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J. F. KELLY, EDITOR

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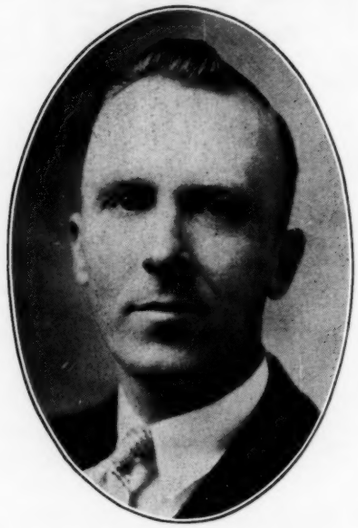

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EDITORIAL

A CAMPAIGN

FOR

NEW USES FOR STEEL

BY

MECHANICAL, COMBUSTION, LUBRICATION, ELECTRICAL AND SAFETY ENGINEERING DIVISIONS

OF

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

Preamble:

The Association of Iron & Steel Electrical Engineers, whose aims and objects are the advancement and development of all forms of engineering to the Iron and Steel Industry, proposes to institute a campaign which will promote New Uses for Steel.

Purpose:

The purpose of this campaign is to find new markets, new outlets, new applications for the use of Steel.

Methods to be Used:

Every member of the Association of Iron & Steel Electrical Engineers will be solicited by a series of letters to offer suggestions and ideas as to what products they feel could be REPLACED BY STEEL.

Incentive:

Cash prize of $150.00 will be offered to the person who makes the first best suggestion.

Cash prize of $50.00 will be offered to the person who makes the second best suggestion.

Cash prize of $25.00 will be offered to the person who makes the third best suggestion.

Cash prize of $5.00 to be offered to the next Fifty-Five persons making the best suggestions.

One prize only to one person.

The prizes to be awarded on the basis of the practicability, utility and economical use of the product suggested.

Judges to be selected from the leading steel companies or the American Iron and Steel Institute.

Instructions to Participants:

All suggestions to be written on plain white paper.

You will be permitted to make any number of suggestions.

Your name, occupation, plant, street number, city and state must appear on each sheet of paper.

Length of Contest:

November 20, 1932 to May 15, 1933.

Prizes to be awarded at the 29th Convention of the A. I. & S. E. E. in June, 1933.

All suggestions to be forwarded to

Contest Editor,
Iron and Steel Engineer,
1010 Empire Building,
Pittsburgh, Pa.

PERTINENT POINTS FOR CONTESTANTS

1. Check up every newspaper and current periodical coming into your office or your home, look over the advertising pages and find out what products advertised could be made OF STEEL.
2. Check up every piece of equipment coming into your factory, your works, your steel plant and find out whether it could be made OF STEEL.
3. Check up every building in your plant, works or factory and see if it could be made OF STEEL.
4. When you come to work every morning and return to your home check up every visible object you see and find out whether it could be made OF STEEL.
5. Check every single unit in your home and see what could be made OF STEEL.
6. Check up everything that comes into your home and see if it could be made OF STEEL.

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Mercury Arc Rectifiers For Steel Mill and General Industrial Applications

By W. E. GUTZWILLER and R. W. DAVIS
Electrical Dept., Allis-Chalmers Mfg. Company, Milwaukee, Wis.

Presented before the A. I. & S. E. E., Philadelphia District Section, February, 1932, Philadelphia, Pa.

Mercury arc rectifiers convert alternating current into direct current without the use of rotating parts.

The application of metal tank type rectifiers to industrial D.C. service will only be dealt with in this paper. It has been assumed that the principle of operation and general construction of rectifiers are known, hence they will not be further discussed in this article.*

Up to the present time, the application of mercury arc rectifiers in this country has been limited almost entirely to the supply of current to electric railways. Close to 400,000 K.W. of rectifier capacity is already installed in this field. Only in a few instances, and then mostly in small capacity units, have they been applied to industrial load. The first installation was made by the Ford Motor Company in Detroit in 1923, and consisted of two 275 K.W., 250 volt rectifiers. No use of this converting apparatus has so far been made in steel mills.

The high efficiency at the higher D.C. voltages and the capability of the rectifier to carry fluctuating load and high momentary overloads, lead to the almost general adoption of the rectifier to railway service. Load conditions similar to those of railway converting substations prevail in a great many industrial plants, using 250 and 600 volt D.C. power.

Where direct current is required in industrial plants for electric drives or for electrolytic work and has to be obtained by conversion, the D.C. power cost is usually high. This is due to the investment in converting equipment and the relatively high conversion losses. It stands to reason that great care has to be taken, therefore, in the proper choice of the converting equipment for a given application, in order that the D.C. power cost be reduced to a minimum. It will be shown in the following, that in many such plants, rectifiers can be applied to great advantage.

As a result of the steady improvements in the reliability of rectifiers and the development, within the last few years, of large capacity units, the application of mercury arc rectifiers is now almost unlimited. They are available in sizes of from 500 upwards to 10,000 Amps., and from 110 volts up to the highest commercial voltages. In railway service, they have supplied currents at potentials as high as 4000 volts, whereas, potentials up to 9600 volts have been applied in electrochemical plants and 15,000 volts in radio broadcasting stations.

According to records available, the first industrial installation of a metal tank type rectifier was made in Europe in 1911 by Brown Boveri & Company, Ltd. The rectifier was rated 57 K.W. at 230 volts and was used for the supply of power to a foundry. Since then rectifiers have found a rapidly increasing demand.

No figures of the total rectifier capacity supplied for industrial loads are available. However, some interesting data on rectifiers of Brown Boveri & Company, Ltd., a pioneer in rectifiers and the largest manufacturer of this equipment in Europe, will be given. Brown Boveri had installed, and on order, up to 1931, over 1,200,000 K.W. capacity of metal clad rectifiers, of which approximately 850,000 K.W. are used by Railway Companies. About 200,000

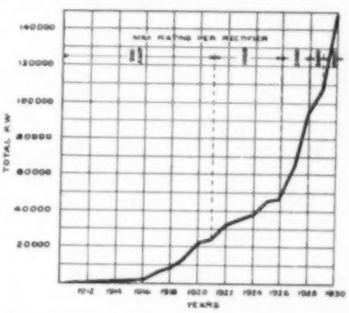

FIG. 1—Total Capacity of Brown Boveri Rectifiers Installed in Industrial Plants. (Rectifiers sold to Utilities and Municipalities for Light and Power Service are not included.)

K.W. are used by Public Utilities and municipalities for light and general purpose power. A further 150,000 K.W. of rectifiers are installed in industrial plants. This capacity is divided in various fields of industrial applications, about as follows:

78,000 K.W. or 52% in electrochemical and electrolytic plants for the manufacture of Hydrogen, Oxygen, Chlorine, Caustic Soda, Zinc and Aluminum.

42,000 K.W. or 28% in Steel Mills for the supply of main roll drives, mill auxiliaries and for D.C. drives of blast furnace blowers.

30,000 K.W. or 20% for miscellaneous industrial applications, such as industrial railways, ore and coal haulage, aerial ropeways, unloaders, dredges, cranes, conveyors, elevators, lifting magnets, process machines and machine shops.

A large portion of these rectifiers supply power between 400 and 600 volts, some being arranged for 230 and 460 volt operation. Many operate at 250 volts and some as low as 110 volts D.C. It may be mentioned here, that while in this country practically all industrial D.C. power for general purpose is supplied at 250 volts, in Europe, both 250 and 500 volts are used quite commonly.

Figure 1, shows the increase of total Brown Boveri rectifier capacity, installed in industrial plants during the years 1911 to 1931. This curve does not include rectifiers on Utility and Municipal systems. The curve is typical for the rectifier development in general. Little progress was made in the use of rectifiers during the first few years. Many diffi-

*For literature on these subjects, we refer to "Mercury Arc Rectifiers, Theory and Practice," by O. K. Marti and H. Winograd.

culties had to be overcome, and the maximum output per rectifier was limited to about 500 Ampere. In case of large installations, several rectifiers often had to be connected in multiple to a common transformer, with the result that first cost, attendance and floor space requirements were excessive. It will be noted from curve, Figure 1, that with the development of 2000 Amp. and larger tanks, the use of rectifiers in the industrial field increased considerably.

In the following, the operating characteristics of mercury arc rectifiers will be discussed and compared with those of motor generators and synchronous converters with particular reference to steel mill and general industrial applications.

Efficiency:

A rectifier unit consists of three principle parts, the rectifier transformer, the rectifier and the rectifier auxiliaries. In comparing rectifiers with rotating type converters, from view point of efficiency, it is necessary to consider the electric losses in all three parts.

The losses in the rectifier transformer are the copper and core losses, which are about equal to the losses in similarly rated transformers for supplying rotary converters. The power required for operating the rectifier auxiliaries depends on the rectifier rating, class of service, and type of cooling. The losses in the auxiliaries are constant for all rectifier loads and amount to 2-3 K.W. for the smaller rectifiers and 4-5 K.W. for the larger ones.

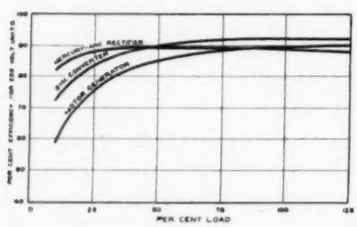

FIG. 2—Overall Efficiency Curves for a 250 VOLT, 1000 K.W. Rectifier, a Synchronous Converter and a Synchronous Motor-Generator Set.
(A.C. Supply, 2300 Volt, 3-Phase, 60 Cycles.)

The efficiency of the rectifier itself is practically constant at all loads. This is accounted for by the fact that the arc drop, which is a direct measure for the efficiency, is little influenced by the D.C. load. This arc drop varies according to size of rectifier, between 19 and 30 volts, the lower value referring to smaller, the higher value to larger units. According to this, the efficiency of the rectifier decreases with increasing capacity. This is contrary to rotating type converters, which show better efficiency in the larger sizes. The efficiency reduction of larger rectifiers, however, is partly compensated for by the better efficiency of the larger rectifier transformers. Since in case of large low voltage units, the rectifier losses present a large portion of the total unit losses, advantage has been taken of the better tank efficiency of small units by connecting two or more of them in parallel to a common transformer.

As explained, the rectifier has an almost constant voltage drop in the arc. The losses produced by this drop and consequently the amount of heat and mercury vapor developed are proportional to the rectifier load current. The applied A.C. voltage and rated D.C. voltage have but little to do with the rectifying process. Rectifiers, therefore, are rated according to current output. The kilowatt rating of a given rectifier increases about proportionally with the D.C. voltage and, as the arc loss is not affected by it, the rectifier efficiency will be higher, the higher the D.C. voltage. At very high D.C. voltage, the overall efficiency of a rectifier unit closely approaches the efficiency of the rectifier transformer.

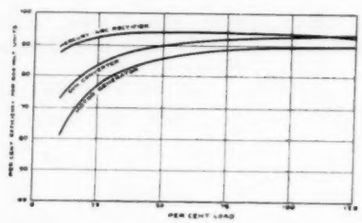

FIG. 3—Overall Efficiency Curves for a 600 VOLT, 1000 K.W. Rectifier, a Synchronous Converter and a Synchronous Motor-Generator Set.
(A.C. Supply, 2300 Volt, 3-Phase, 60-Cycle.)

Figures 2 and 3, show the overall efficiency of a typical 1000 K.W. rectifier unit, of a synchronous converter and of a synchronous motor-generator set at various loads and for 250 volt, as well as for 600 volt D.C. service. In case of the rectifier, the losses included are those of the transformer, the rectifier, connecting leads between transformer and rectifier and of the rectifier auxiliary equipment. The efficiency of the motor-generator is based on the losses of an 80% P.F. synchronous motor, and the D.C. generator losses. In case of synchronous converter, the losses included are those of the converter, transformer and A.C. bus between converter and transformer. All comparisons are furthermore made on the base of 25% overload for two hours and 100% for one minute and an A.C. supply of 2300 volts, 3 phase, 60 cycles.

It will be noted from Figure 2, that at 250 volts, the synchronous converter is slightly more efficient than the rectifier above 50% load, but less efficient below this value. At full load and above, rectifier and motor-generator are equal in efficiency, however, at lighter loads, the rectifier shows a distinct advantage. According to the curve, Figure 3, there is little difference at 600 volts between rectifier and rotary efficiency from half to full load. At lighter loads, however, the rectifier is at an advantage. The 600 volt motor-generator is considerably less efficient than the rectifier over the entire load range, especially at lighter loads. Where A.C. power over 6600 volts is to be converted, it is usually desirable in case of motor-generators, to provide a step down transformer, whereby the conversion efficiency is further reduced.

The load in industrial D.C. systems with exception of electrolytic plants, is usually subjected to heavy fluctuations, and since such D.C. systems, on account of feeder losses, cannot be extended very far, substation-and machine load-factors are generally low.

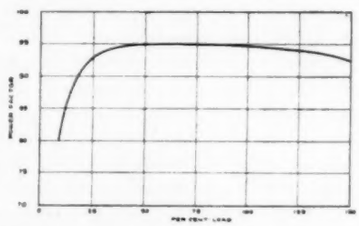

FIG. 4—Typical Power Factor Curve of a Mercury Arc Rectifier.

In order to show what the high rectifier efficiency, under low load factor conditions means in actual

Type of converting apparatus	Rectifier				Synchr. Converter				Motor-Generator			
D.C. Voltage	250 Volts		600 Volts		250 Volts		600 Volts		250 Volts		600 Volts	
Load Factor in per cent	25	50	25	50	25	50	25	50	25	50	25	50
Conversion efficiency in per cent	88.5	89.5	92.5	94.0	83.8	90.0	86.7	91.9	76.3	85.5	77.1	86.2
Average D.C. output in Kw.	250	500	250	500	250	500	250	500	250	500	250	500
Average A. C. input in Kw.	282	558	270	532	298	556	288	544	328	585	324	580
Average conversion losses in Kw.	32	58	20	32	48	56	38	44	78	85	74	80
For 10-hours daily operation 300 days per year:												
Yearly cost of rectifier cooling water at 50¢/1000 cu. ft.	$48	$95	$20	$40	—	—	—	—	--	—	—	—
Yearly cost of conversion losses at ¾¢/kwh. including cooling water	$768	$1405	$470	$760	$1080	$1260	$850	$980	$1760	$1910	$1670	$1800
Savings in favor of Rectifier	—	--	—	--	**$312**	**None**	**$380**	**$220**	**$992**	**$505**	**$1200**	**$1040**
For 24 hours daily operation 365 days per year:												
Yearly cost of rectifier cooling water at 50¢/1000 cu. ft.	$140	$280	$58	$117	—	—	—	—	—	—	—	—
Yearly cost of conversion losses at ¾¢/kwh. including cooling water	$2240	$4100	$1378	$2217	$3180	$3680	$2480	$2860	$5140	$5570	$4870	$5250
Savings in favor of rectifier	--	--	—	--	**$940**	**None**	**$1102**	**$634**	**$2900**	**$1470**	**$3492**	**$3033**

TABLE I.

savings, the yearly conversion losses, when using a 1000 K.W. rectifier, rotary converter and motor-generator have been computed. The comparison of conversion losses is made for 250 and 600 volt service, for 25 and 50% average load factor for each type of conversion device, for 10-hour daily service and 300-day year, as well as 24-hour service, 365 days per year. The conversion losses are based on efficiency curves Figures 2 and 3. For reasons of simplicity, it has been assumed that the average conversion efficiency at 25 and 50% load factor is equal to the machine efficiency at 25% load and 50% load respectively. The losses computed in this manner will differ but little from the actual losses. The data are given in Table I.

In the case of the rectifier, the cost of cooling water has been added to the power cost, the water being figured at the rate of 50 cents/1000 cu. ft. In small plants, water may be purchased from municipalities at this and lower rates. In industrial plants having their own water supply, the cooling water will cost considerably less.

The figures in Table I, clearly show that in installations with less than 50% machine load factor, a substantial power saving can be obtained by the use of rectifiers. The power savings of rectifiers increase with decreasing load factor and increasing D.C. voltage.

Since the efficiency of rotating type converters is lower than for rectifiers at partial load, an efficiency improvement of converter-or motor-generator-plants with fluctuating load, can be obtained by the installation of rectifiers. The voltage regulation of the rectifiers has then to be chosen such that in parallel operation the converters or motor-generators work close to full load where they have their maximum efficiency. while the fluctuating load is being taken by the rectifiers.

Power Factor:

A typical rectifier power factor curve is shown in Figure 4. It will be noted that the power factor is practically constant and close to unity, from full load to about 25% load. At 10% load, it reaches approximately 80%. A mercury arc rectifier cannot furnish leading current for power factor correction. Since, however, the power factor is close to unity, the plant power factor will not be reduced by the addition of rectifier equipment. On the contrary, the rectifier will exert a correcting influence on low power factor systems. In this respect, it is similar to the synchronous converter. In substations with heavily fluctuating load and low machine load factor, a much better average power factor will be obtained with rectifiers than with synchronous converters.

Overload Capacity:

The rectifier is capable to carry high overloads of short duration. Repeated D.C. short circuits, if cleared by ordinary breakers, will not harm the rectifier. This is due to the elimination of all current collecting parts, the entire absence of synchronizing forces and the cooling by circulating water. While the maximum overload capacity of rotating converters is less than for rectifiers and is limited by commutation, they have more masses to store heat, and hence, can carry lesser overloads for a longer period.

Where heavy overloads of longer duration are

anticipated, it will be necessary to under-rate the rectifier somewhat, so that it will normally operate below its maximum rating determined by temperature rise. Contrary to rotating converters, such under-rating does not result in any noticeable reduction of the rectifier efficiency.

The high momentary overload capacity of the rectifier is a desirable feature for application to main roll drives, for steel mill auxiliaries, material handling and haulage, for machine shops, etc. When applying rectifiers to a fluctuating load with heavy peaks, it has to be kept in mind that the load variations on the D.C. end, due to the absence of flywheel effect, are carried through the rectifier into the A.C. supply system without being dampened. This may cause voltage and frequency fluctuations in small A.C. systems.

Voltage Characteristics and Parallel Operation:

The natural voltage characteristic of a mercury arc rectifier unit is a drooping one and is primarily due to the reactance drop of the rectifier transformer.

FIG. 5—Six 5000 Amp. 460/560 Volt Mercury Arc Rectifiers Installed in a Canadian Electrolytic Zinc Plant.

The voltage regulation depends on the type of transformer connection employed and is usually 6-7% for 250 volt units, 4-6% for 600 volt units. Substations supplying D.C. power to material handling equipment, cranes, elevators, process machines, machine shops, where the converting apparatus, as a rule, are located close to the load, the shunt characteristic of the rectifier is desirable. It assures inherent stable parallel operation, (without the use of equalizers) of two or more units in same station and proper load division between substations. The shunt characteristic is especially valuable under fluctuating load and in the parallel operation of automatic substations.

Rectifier transformers are always provided with suitable primary taps and no load ratio adjusters. They allow for adjustment of the rectifier full load voltage to the normal value and permit compensation of seasonal changes in the A.C. supply voltage. There are schemes available for compounding rectifiers. The compounding may be obtained by D.C. magnetization of the inter-phase transformer, proportional to the load current. Compounding in this manner, however, is not economical, as it requires larger transformers, and results in lower efficiency and power factor.

Where voltage adjustments under load are a necessity, it has been common practice, in the past, to provide either load tap changing on the rectifier transformer or to install a separate regulating transformer. Automatic tap changing has been applied in many instances with this method of voltage control. The rectifier voltage is regulated in steps, the voltage range and number of steps is limited on account of the equipment cost. A 25% range has been found to be about the maximum economical limit for industrial applications. With few exceptions, all large capacity rectifiers, so far applied to rolling mill drives have been provided with load tap changing. The mill motors in these plants are started on the lowest rectifier voltage, using either resistors or reactors for limiting the starting current.

Induction regulators or D.C. booster machines have also been applied, but have found little use in modern rectifier substations, in view of their relatively high cost and electric losses.

In view of the above voltage characteristics, the rectifier so far could not be considered for installations requiring a wide adjustable voltage range. Its application has particularly been defined to constant voltage conversion.

One of the most recent and promising developments in the power rectifier field, are electrically controlled grids. An insulated metallic grid is inserted in the arc path between each anode and the cathode. By applying a suitable potential to these grids, the electric field between the electrodes is modified such that the instant at which an anode starts to work, can be delayed at will, whereby the average D.C. voltage of the rectifier is reduced. However, as a result of the delay in the working period of the anodes, the power factor of the rectifier is reduced. The power factor reduction is approximately proportional to the reduction of the D.C. voltage. With this simple method of voltage control, which does not complicate the rectifier, it has become possible to give a rectifier almost any compounding characteristic. Furthermore, the voltage may be regulated over a wide range permitting the starting of large D.C. motors by the low voltage method. The load of a unit or substation may be limited or shifted to other stations with this type of voltage control. The starting of large D.C. systems supplied with rectifiers after A.C. power failures, becomes a simple matter. The grid control, furthermore, is helpful in the degassing of the rectifier, in starting the rectifying arc, and in the prevention of valve failures or backfires.

This control opens up new fields for the application of power rectifiers, especially in steel mills. It may eventually lead to the adoption of rectifiers for Ward-Leonard Control.

The general rule, requiring similar voltage characteristics for paralleling D.C. machines, applies also to the paralleling of rectifiers with one another, or with rotary converters or motor generators. In rectifiers, as well as in rotaries, any change in the A.C. voltage, proportionally affects the D.C. voltage, whereas motor-generator sets are not affected by A.C. voltage changes. Rectifiers and rotaries, therefore, parallel when supplied from a system with fluctuating voltage. Certain precautions must be taken when paralleling rectifiers with motor-generator sets. Conditions in this case are similar as with the paralleling of rotaries and motor-generator sets, except that the rectifier has the advantage that no reversal of current takes place when its voltage drops below the bus voltage. A further advantage in favor of the rectifier, is the fact that variations in frequency of the supply have no effect on the rectifier, whereas it has a considerable bearing on the operation of rotaries and motor-generator sets.

Control and Protection:

Starting and stopping of a rectifier are extremely simple and may be compared with the switching in and out of a transformer bank. The starting consists merely of closing the rectifier A.C. and D.C. breakers. The arc striking device and excitation anodes are energized simultaneously with the closing of the A.C. breaker through one of its auxiliary contacts. Through a similar contact is the cooling water turned on by an electrically operated water valve. The unit is shut down by tripping D.C. and A.C. breaker. No harm can be done to the rectifier, if the sequence of breaker operation on starting and stopping is reversed.

Rectifiers are generally protected only against overload, reverse current, excessive tank temperature, cooling water and vacuum failures. In view of the small number of protecting features and simplicity in starting and stopping, rectifiers are very suitable for automatic control. The control is simple and inexpensive compared with the control of rotating type converters.

The majority of manually operated Rectifier Plants are nowadays equipped with thermostatic control of the cooling water and with automatic vacuum control. The latter control automatically maintains the vacuum in the rectifier within the safe operating range, independent of the rectifier load. A station with automatic vacuum and water control, does not require a regular attendant. A few daily inspections of the station are sufficient. It has become a practice, especially in industrial installations, to provide an alarm-system which indicates in the nearest attended substation, the opening of a breaker, excessive rectifier temperature, vacuum or water failure. A rectifier unit may be remote controlled by the addition of electric control and automatic reclosers for A.C. and D.C. breakers. Full automatic starting and stopping of the plant may be obtained by a time switch or load responsive control apparatus.

Floor Space, Weight and First Cost:

At 250 V., the actual floor space occupied by a rectifier and its transformer is about the same as for a synchronous converter unit, whereas, motor-generators up to about 6600 V. A.C. supply, require only 75-80% of the rectifier or rotary space. With higher supply voltages, step down transformers are usually employed with motor-generators in which case they need 30-40% more space than the rectifier. While the floor space requirements of 600 volt rotaries and motor-generators is about the same as for 250 volt machines, the rectifier requires only about 80% of their space. In case of rotating type converters, considerable additional space has to be provided for removing the armatures. Little extra space is needed for overhauling rectifiers, with the result that the actual substation floor space for rectifiers is approximately one-half of the space for rotating converters. A typical example demonstrating the above is illustrated in Figure 5. The picture shows a large converting substation in a Canadian Electrolytic Zinc Plant. The substation contains ten 4500 Amp. 470/550 volt Booster type, 60 cycle Rotary converters and six 5000 Amp. 460/560 volt Mercury Arc Rectifiers. It will be noted that the six rectifiers are installed in three substation bays, whereas the ten rotaries occupy about thirteen bays. Approximately three times more rectifier than rotary capacity is therefore installed per substation bay. The space occupied per unit by the transformer-switching-and control-equipment in this plant, is about equal for both types of converting apparatus.

The installed weight of 250 and 600 volt rectifiers is only 70-80% of the rotary converter weight and still less in case of motor-generators. The difference in weight becomes greater for the larger units, on account of their lower speed.

The first cost of manually operated, 250 volt, rectifiers is somewhat higher than for motor-generators and synchronous converters. Above 500 volts, however, the cost of rectifiers and rotating type converters is about equal. When comparing cost of automatically controlled conversion equipment, rectifiers as a rule show an advantage over their competitors. This is accounted for, by the low cost of the automatic rectifier control.

In many instances, the higher first cost of 250 volt rectifiers is fully compensated for by savings in installation cost.

Substation Design:

Due to the light weight of the rectifier, and the absence of vibrations, no special foundations are required. In this respect, the rectifiers are again similar to transformers, requiring just enough foundation

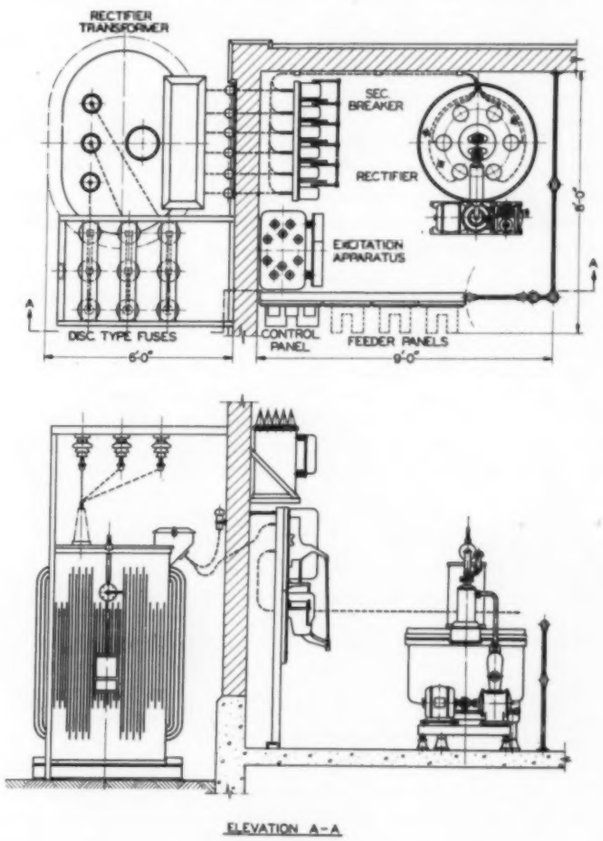

FIG. 6—Typical Layout of a 300 K.W., 250 Volt Rectifier Unit Installed in an Industrial Plant.
(A.C. Supply, 13,200 Volt, 3-Phase, 60-Cycles)

to carry their weight. Since all losses are carried away by the cooling water, no special provisions for substation ventilation will have to be made. With the elimination in the rectifier substation, of a strong draft of air, such as required for the ventilation of rotating machinery, very little dust is carried into the rectifier room, resulting in reduced maintenance cost. The rectifier is metallically enclosed, perfectly

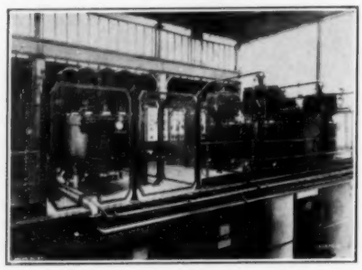

FIG. 7—Four 1000 Amp. and One 4200 Amp., 500/540 Volt Rectifiers Installed in a Rolling Mill.

sealed against the atmosphere, and all the exposed insulation consists of porcelain. Hence it is immune to acid and metal fumes, dust and moisture, frequently found in the atmosphere around steel mills, chemical and electrolytic plants. Rotating type converters, when installed in such plants, often require expensive air conditioning equipment, which increases the floor space requirements and complicates the substation layout. Rectifiers may, therefore, be installed in the same building or room where the D.C. power is consumed, and thus, unnecessary feeder losses are avoided.

The rectifier is especially fitted for underground installations, in fact it may be stowed away in almost any available corner or in places where, due to atmospheric conditions, the average types of electrical equipment could not be even considered.

For untanking a rectifier for the purpose of repair or cleaning of water jackets, the active parts have to be lifted only vertically. Furthermore, the rectifier supporting legs are usually arranged so that the entire rectifier or only the water tank can be lowered on to a three-wheel truck. Costly traveling cranes can, therefore, be avoided. A ceiling hook and chain block is all that is required for overhauling a unit. Where the station head-room is limited, such as in basement installations, the clearance above the rectifier can be reduced to a few inches. However, in case any overhauling work has to be done, the rectifier, with the aid of the above mentioned transportation truck, will have to be moved underneath a hatchway or other place, where there is sufficient head-room and a lifting device.

With the smaller units, there are usually six, and with the larger ones, twelve, eighteen or even twenty four cable connections between the rectifier transformer and the rectifier. In order to keep the cost of these cables and their installation down to a minimum, it is desirable to have the transformer and rectifier located close to each other. For an outdoor transformer, an arrangement, as shown in Figure 6, is recommended. With all indoor equipment, and with no particular limitations in floor space, the transformer may be placed close to the rectifier and the secondary cables carried over-head. Where floor space is limited, the transformer may be put in the basement, preferably directly underneath the rectifier, as is the case in installation, shown in Figure 5. With sufficient head-room available, the rectifier being the lighter portion of the complete unit, may be placed on a gallery or elevated structure, with the transformer installed in a suitable compartment beneath the rectifier. An arrangement of this type is shown in Figures 7 and 9.

The rectifier tank, when in operation, is alive. Its potential to ground varies and may, in case of a negative ground, reach a value equal to the D.C. system voltage. Consequently rectifier tanks cannot be grounded. As protection against accidental contact in 250 volt installations, railings are usually placed around the rectifier, while 600 volt rectifiers, are screened in, as shown in Figures 5 and 7. As a further protection, the floor around the rectifier tank is sometimes covered with rubber mats or cork linoleum.

Figure 6, shows a typical layout of a 300 K.W., 250 volt rectifier unit installed in an industrial plant for the supply of an isolated D.C. load. The A.C. supply of 13,200 volts is connected to the rectifier transformer through disconnecting type fuses. The high tension oil circuit breaker is eliminated and all the switching is carried out by a six-pole air breaker in the anode circuits, no D.C. machine breaker being used. The floor space required for the rectifier, the auxiliaries and control board is 8 x 9 feet and for the high tension outdoor equipment 6 x 8 feet, making the total floor area 8 x 15 feet.

The elimination of high tension breaker and metering equipment, will represent quite a saving for A.C. supply voltages above 15 KV. The application of a secondary air breaker, however, is limited to small rectifier units, as its cost becomes excessive for large current ratings and more than six-poles. With the application of a secondary breaker, the rectifier transformer remains permanently connected to the A.C. system. Where the rectifier is in service during the larger portion of the day, the small power loss in the transformer, with the rectifier off, is seldom objectionable.

Operation:

As already explained, starting of a rectifier consists mainly in connecting it to supply and load. According to the valve action, energy can only flow from the A.C. to the D.C. system, consequently in starting, there is no need for checking D.C. polarity and voltage before connecting the unit to the bus. An incoming unit takes automatically its share of load and no rheostat adjustment is required to properly divide the load between units. Equal load division between sets is assured under most adverse load conditions. No harm can be done to the rectifier, if in starting or stopping, the sequence of breaker operations is reversed. Rectifiers can be started and safely operated on reduced frequency, A.C. voltage and phase unbalance. From the above it can readily be seen that manually operated rectifier substations do not need any skilled operators. The possibility of damaging the rectifier equipment by faulty operation is extremely remote.

In case of failure of the A.C. supply, rotating converters must be disconnected and can only be started after normal supply line conditions are fully restored. This often results in a prolonged shut down of the plant and consequently a loss of production. A rectifier is usually only disconnected in

the event of severe overloads or fault in the D.C. system. Upon an A.C. failure, the rectifier remains connected to supply and load and is ready to deliver current immediately the supply is restored. Even while the after effects of a line disturbance, such as low frequency, reduced A.C. voltage and phase unbalance still prevail, the rectifier may be put back on the line and supply at least power at reduced voltage to the most essential drives of the plant.

Due to the absence in the rectifier of synchronizing forces and revolving masses opposing sudden changes in supply line conditions, the rectifier shows unusual stability during A.C. line disturbance. There are many cases on record where during A.C. disturbances, service from all synchronous machinery of a system was lost, while the rectifiers stayed on the line and were called upon to carry an excessive emergency load.

Where two A.C. supplies of different frequency are available, a rectifier unit may be operated on either system. In this case the transformer equipment will have to be designed for operation on both frequencies. Changeover from one to the other supply is merely a switching operation which can be carried out instantaneously and automatically upon failure of one power source.

Many industrial plants, generating their own power at 25 cycles, may consider a changeover to 60 cycles in the future, others may be induced by Power Companies to purchase 60 cycle off-peak power at an attractive rate. In some plants, 60 cycle power is already being purchased and must be converted into 25 cycle power through frequency changers. Where such conditions prevail, rectifiers where they are otherwise practical, should be given serious consideration for all future extensions.

Another feature of interest, is the possibility of operating one and the same rectifier at different D.C. voltages without appreciably changing the current rating. A unit may for instance be built for operation on either 250 or 500 volt service, changeover from one to the other voltage being obtained by series-parallel connection of the rectifier transformer secondary winding. This feature is of interest, particularly to steel mills, for the power supply to both, 250 volt auxiliary service and to 500 or 600 volt power for main drives. One rectifier tank only need be carried as spare for the units serving the two systems.

Since in a rectifier power, under normal conditions can only flow from the a-c to the d-c system, rectifiers can ordinarily not be considered for regeneration. Nevertheless they can be applied to systems with regenerative breaking of motors, provided they are operated in parallel with motor generators or where the regeneration amounts to a small portion of the total system load. Here again successful experiments with electrically controlled grids have already been made. It is anticipated that with the use of these grids it will soon be possible to regenerate with rectifiers.

Maintenance:

The rectifier has no parts subjected to wear, such as brushes, commutators and bearings. The anodes do not give off nor receive material. The cathode mercury which evaporates by the heat of the arc, condenses as soon as it comes in contact with the water cooled tank walls and returns to the cathode by gravity. Rectifiers require, therefore, little attendance and maintenance. Figures available on a number of 600 volt railway rectifiers and synchronous converters, indicate that the maintenance cost of rectifiers based on the K.W. hour output is only about 50% of the rotary converter maintenance cost. The maintenance savings derived from rectifiers are still greater in Electrochemical and Electrolytic Plants. In this class of service, the replacement cost of brushes and cost for commutator upkeep are high on account of abrasive dust, acid-and metal-fumes in the air.

The seals and weldings of the vacuum chamber of modern rectifiers, as well as their evacuating equipment have been improved to such an extent that little or no attention is required in maintaining the vacuum.

Corrosion of the rectifier cooling jackets and sludge deposits may develop where the cooling water is not of proper quality. Under such conditions, the cooling jackets need to be flushed out occasionally or may need scrubbing and painting. Provisions have been made in the rectifiers, such that this cleaning work can easily be carried out without having to break the vacuum. In steel mills, where the water available for cooling is usually not very clean, indirect cooling will have to be considered for the rectifier, by means of heat exchange units.

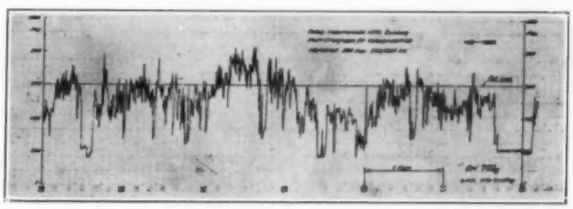

FIG. 8—Load Chart of a 6000 Amp., 450/550 Volt Rectifier Unit Supplying Power to a Rolling Mill.

Records from a number of installations, indicate that the yearly cost of replacement parts per rectifier, varies between 50 and 100 dollars. The lower figure refers to smaller units, the higher figure to the large ones. These figures cover cost of miscellaneous packing material, oil for the rotary vacuum pump and makeup mercury for the mercury vapor pump and rectifier seals.

It may be mentioned here, that age seems to have no effect on rectifiers. The experience with installations made over fifteen years ago, rather indicates that the rectifiers improve with age. This is attributed to the gradual exhausting of the very last traces of foreign gases in the tank, with the result that after a number of years of operation they reach and maintain an almost perfect degree of evacuation. In view of these facts, rectifiers have a higher resale value and consequently their rate of depreciation should be lower than for rotating type converters.

Description of Some Typical Installations:

Figure 7, shows mercury arc rectifiers installed in a rolling mill of the S. A. d'Ougrée Marihaye at Ougrée, Belgium. At the right are four 1000 Amp. 500/540 volt rectifiers connected in pairs to two transformers. These units were ordered in 1924, at a time when 1000 Amp. was the largest cylinder capacity. To the left, is shown a 4200 Amp. 500/540

volt rectifier. This unit was ordered in 1930, as a result of the satisfactory performance of the 1000 Amp. units. The rectifiers are provided with load tap changing equipment. Other rectifiers used for rolling mill service by this company are an additional four 1000 Amp. units, one 1500 Amp. and two 4200 Amp. units.

A large capacity rectifier unit was put in service in October last year by the Vereinigte Stahlwerke A-G Duisburg, Germany, for the power supply to rolling mills. The unit is rated 6000 Amp. 450/550 volt, 2700/3300 K.W., and is provided with regulating transformer and automatic voltage control. Due to a steady reduction in the output of the blast furnaces in this plant, during the last few years, there was no longer sufficient furnace gas available for the generation of all D.C. power by gas engines. As a result of the shortage on blast furnace gases, the Vereinigte Stahlwerke decided to purchase A.C. power from a local Utility and had it converted by the above mentioned rectifier unit. The rectifier serves, therefore, as a support for the gas engine plant with which it is operated in parallel. Provisions have been made for the ultimate installation of three 6000 Amp. rectifiers with a possibility that rectifiers will eventually be used entirely for the supply of rolling mills. According to reports, the roll motors are started on low voltage by a gas engine generator. Speed regulation is obtained by Ward-Leonard control. At the present time, there are also a number of large variable speed pumps connected to the rectifier. Figure 8, shows a typical 6-hour load chart taken on this rectifier while it was supplying the rolling mills and carrying at the same time a pump load of 2000 Amps. This base load will be noted at the right end of the chart. As can be seen, the average load of this unit, when rolling is close to full load. The rectifier has operated to the entire satisfaction of its user.

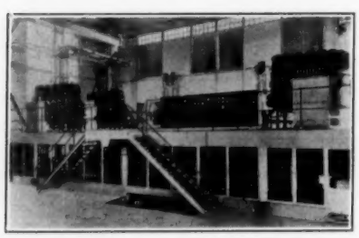

FIG. 9—Three 8500 Amp., 590 Volt Rectifiers Used for Power Conversion in an Aluminum Plant.

Other large capacity industrial installations worth while to be mentioned are:

Two 2000 K.W., 525 volt rectifiers for the supply of variable speed D.C. motors driving blast furnace blowers.

One 2200 K.W., 3500/9600 volt rectifier for the supply of a special arc furnace. This equipment is installed in the United States.

Three 6000 Amp., 435/560 volt, four 6000 Amp., 650 volt and two 5500 Amp., 700 volt, rectifier units, all for power supply to Hydrogen cells, and installed in three different plants.

Six 5000 Amp., 460/560 volt rectifiers for the power conversion of an Electrolytic Zinc Plant. This installation is shown in Figure 5.

Three 8500 Amp., 590 volt units for the supply of D.C. power to Aluminum pots. The rectifiers are shown in Figure 9.

An interesting rectifier installation was made in 1924 in a German Steel Mill. It consists of eight 600 Amp. rectifiers, of which two units are for straight 500 volt power service, two units for straight 250 volt lighting service. The remaining four units are provided for operation on either the 500 or 250 volt system, changeover from one to the other voltage being obtained by series/parallel connection of the transformer secondary winding.

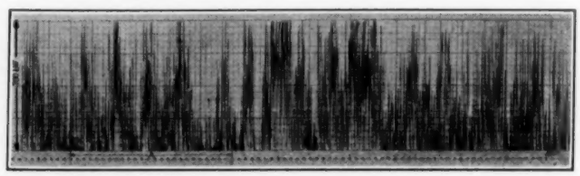

FIG. 10—D.C. Load Chart of Two 550 K.W., 500 Volt, Flywheel Motor-Generators, Supply Power to Loading Bridges. (A represents one hour operation)

A somewhat similar installation was made four years ago in an Australian Ship Yard. The rectifier is rated 1000 Amp., and has three operating voltages, namely, 480 volts for machine shop supply, 220 volts for shop lighting and 110 volts for lighting ships from the shore while undergoing repairs and for battery charging. The rectifier is equipped with two transformers, which by means of disconnecting switches can be connected according to voltage requirements. In spite of the low operating voltages and small output of the rectifier, an annual saving of approximately 14% of the invested capital has been realized.

In 1926, a 700 K.W., 500 volt rectifier set was installed in a large coal and ore unloading plant in the port of Rotterdam. The rectifier supplies two 20-ton and two 12½-ton electrically driven loading bridges, and replaced two old 550 K.W. flywheel type induction motor-generator sets. Due to an increase of the A.C. system capacity, the flywheel effect was no longer required. The principal reason for installing the rectifier was in order to improve the conversion efficiency and reduce operation and maintenance cost. Since its installation, this rectifier has been in operation continuously day and night, except Sundays and fulfilled all expectations. Figure 10, shows a load chart taken on this rectifier. The chart is typical for a loading plant. Previous to the rectifier installation, input and output of the motor-generators, was metered over five typical working days. Tabulation II, gives the meter readings, and the corresponding motor-generator efficiency. Due to the fluctuating load and low load factor, the average efficiency of the motor-generators for the five days is only 67.8%. The rectifier average overall efficiency over the same period has been computed to 92.6%. Thus, with the use of the rectifier, a power saving per working day of 1747 Kwh will be realized. This corresponds, at a power rate of ¾-cent/Kwh. to a yearly power saving of approximately $4,000. which is over 20% of the rectifier investment. It has to be noted that a synchronous motor-generator set would have at least 5% higher efficiency, than the above flywheel induction motor-generator. Further savings in this plant were obtained, due to the elimination of a regular attend-

ant, since the plant was originally operated on a three shift base.

Assuming that the above rectifier had been rated 250 volts instead of 500 volts, then the average rectifier efficiency under same load conditions would be approximately 86%. The yearly power savings over the motor-generators would be in this case about $3,100 or 16% of the rectifier investment. The above figures prove that rectifiers, on account of their high efficiency at partial load, permit a very efficient power conversion in plants with heavily fluctuating load.

Conclusions:

In the foregoing article, industrial applications of Mercury Arc Rectifiers, with particular reference to steel mills have been discussed. It has been shown, that in Europe, rectifiers of the metal tank type have been successfully employed in the industrial field for years. With the more recent development of large units, their total capacity in this field has more than tripled within the last four years. Relatively little use of the rectifiers in the industrial field has been made in this country.

The operating characteristics of rectifiers, resemble very much those of the synchronous converter, yet the rectifier has a number of features which the rotary lacks and which are desirable for industrial power conversion. The rectifier shows, especially better efficiency and lower operating cost than motor-generators, but lags in the ease of voltage control and the power factor correction features.

Date January 1927	Primary Input Kwh	Direct-Current Output Kwh	Efficiency of the Motor-Generators	Efficiency of the Rectifier
24	4737	4380	67.7%	92.4%
25	4738	4390	67.7%	92.6%
26	4851	4490	68.0%	92.5%
27	5103	4720	68.7%	92.5%
28	4438	4130	66.9%	93.0%
	4773	4422	67.8%	92.6%

TABLE II

The economy of the rectifier over rotating type converters is most pronounced at or above 500 volts direct current, but at voltages even as low as 250 volts, proves to be more economical than motor-generators and rotaries, especially for installations where:

A large dange of D.C. voltage control under load is not required.

The A.C. supply voltage is above 6600 volts.

No power factor correction is required.

Daily machine load factor is 50% or less.

Remote or full automatic control is required.

DISCUSSION

Discussion Presented By

R. F. Gale, Plant Engineer, Midvale Company, Nicetown, Philadelphia, Pa.

W. E. Gutzwiller, Electrical Dept., Allis-Chalmers Mfg. Company, Milwaukee, Wis.

G. Pfeffer, Electrical Supt., Florence Pipe Foundry & Machine Company, Florence, N. J.

E. W. Ross, Engineer, Baldwin Locomotive Works, Eddystone, Pa.

J. M. McTamney, Electrical Engineer, Midvale Company, Nicetown, Philadelphia, Pa.

J. H. Cox, Section Engineer, Circuit Breaker Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

R. E. S. Pope, Department of City Transit, City of Philadelphia, Philadelphia, Pa.

R. F. Gale: I think Mr. Gutzwiller's paper on Mercury Arc Rectifiers has been more ably and more simply presented than ever before.

I have one question: I understand that in the construction of a rectifier the inside surfaces have to be unusually smooth. Is this true and why?

W. E. Gutzwiller: The inside surfaces of a rectifier tank usually have sandblast finish. With the sandblasting it is possible to effectively remove all traces of scale, paint, oil and dirt. Such substances, when exposed to the heat of the arc, would give off gases which would cause a breakdown of the rectifying action. It is, therefore, essential that a rectifier tank is carefully cleaned out before it is sealed up.

R. F. Gale: I have another question: When the mercury arc rectifier is overloaded or abused what would be the nature of the failure and length of shutdown to be expected?

W. E. Gutzwiller: If a rectifier is subjected to excessive overloads, the anodes may become pitted; that is, rough spots will be produced on their working surface. Once such rough spots are developed, the arc has a tendency to concentrate on them until holes are burnt. This requires refinishing of the anode surface.

Excessive overloads also produce an excessive amount of mercury vapor, which, if it cannot be absorbed rapidly enough by the cooled tank walls, will cause a rise in vapor pressure resulting in a breakdown of the valve action. Such breakdowns are called "backfires" or "arc backs". They are about the equivalent of a secondary short circuit on the rectifier transformer. In case of a backfire, the overload relays cause the instantaneous tripping of A.C. and D.C. breaker of the rectifier unit, such disconnecting it from supply and load. The backfiring anode is thereby extinguished, whereupon the rectifier is immediately ready to again carry its load. A backfire does not cause any damage in the rectifier nor transformer, if it is cleared by the rectifier switchgear in a reasonable time.

No backfiring has been experienced on rectifiers with a rated D.C. voltage of 300 volts or less. In

modern rectifiers, backfires have been practically completely eliminated at the higher voltages. We have, for instance, two 2500 K.W., 630 volt rectifiers on the subway right here in Philadelphia which, I believe, in spite of severe load conditions did not have a single backfire during 1931.

G. Pfeffer: I want to say I am very glad to have had the opportunity of listening to Mr. Gutzwiller's paper. One of the questions I had in mind was the overload. That has just been answered. Another question I would like to ask is, does the mercury have to be renewed very often?

W. E. Gutzwiller: Under normal operating conditions, there is no loss of mercury.

Due to improper cooling under overload, there is a remote possibility that mercury, in form of vapor, may find its way from the rectifier over to the mercury vapor pump. This may eventually result in the flooding of the pump by mercury. Special baffles and cooling jackets are, however, provided in the pipe line between rectifier and pump which prevent the transfer of mercury from the rectifier to the pump.

G. Pfeffer: One other question I have in mind. When you have submersion due to a flood, how long does it take to restore the service? What damage does a flood do?

W. E. Gutzwiller: A leak which may develop on a mercury seal can, as a rule, be stopped by simply tightening up the seal flanges. If, after several years of service, a sealing gasket has become dry and brittle, it may be necessary to replace the gasket in order to stop the leak. Depending on the location of the gasket, sometimes an anode or an anode bushing has to be removed in order to exchange the gasket. This necessitates the admission of air to the rectifier bowl. After such repairs, which require only a few hours, the rectifier is evacuated by the vacuum pump and put back in service. If possible, the rectifier should not be called upon to immediately carry heavy load as the vacuum may drop otherwise to a dangerously low value.

If, due to a more serious repair, a rectifier tank has to be exposed to atmosphere for several days, it will be necessary to evacuate it under heat in order to remove all moisture and gases. The heating may be produced by either artificial load, electric tank heaters or by circulating hot water through the cooling jackets. This process may take from 12 to 24 hours depending on conditions, and is called the baking out or forming of the rectifier.

G. Pfeffer: I have another question. What is the average life of an electrode and the cost of a 500 k.w.

W. E. Gutzwiller: To my knowledge, we never had electrodes damaged under normal operating conditions.

I recall only two or three instances where anodes were damaged and had to be replaced due to either faulty material, incorrect operation of the rectifier or failure of a breaker to remove the rectifier from service during short circuits.

G. Pfeffer: Are they costly?

W. E. Gutzwiller: We use steel anodes for all our standard rectifiers; for special applications graphite anodes are used. The cost of an anode is approximately thirty dollars.

G. Pfeffer: Why do you use carbon on the large ones?

W. E. Gutzwiller: Steel anodes are mechanically stronger and absorb less gas than graphite anodes. They are, however, not so heat resisting as graphite electrodes.

E. W. Ross: Do you have any trouble with mercury adhering to the surface of the tank?

W. E. Gutzwiller: This occurs in a tank which has not been cleaned out carefully. As I have already explained, due to the burning up of impurities, gases are produced which may cause the break down of the valve action, i. e., produce a backfire.

E. W. Ross: What does reversal do?

W. E. Gutzwiller: If at the moment of the backfire the rectifier is operated in parallel with D.C. machinery or other rectifiers, a reverse current will flow into the rectifier. For this reason it is essential for the quick extinction of a backfire, that suitable relay protection be provided so that the A.C. and D.C. breaker of the rectifier unit are tripped.

J. M. McTamney: I agree with Mr. Gale that we are indebted to the writer of this paper, as it has proven very interesting and should be of value to the Steel Industry.

The efficiencies were given at one-half and one-quarter loads, compared with rotaries and motor-generator sets at these same loads. If efficiencies were compared at higher loads the saving would not be so attractive and an Industrial Plant purchasing power from a Public Utility and having the means of keeping converter equipment fully loaded by taking peak loads on their own generator plant should consider this.

I would like to ask the starting peak on Mercury Arc Rectifiers.

W. E. Gutzwiller: A rectifier has no starting peak. Starting a rectifier consists principally in connecting the rectifier transformer to the primary supply. The starting current is, therefore, equivalent to the transformer magnetizing current.

J. M. McTamney: Is it not necessary to strike an arc?

W. E. Gutzwiller: This is done by means of a 110 volt single phase, auxiliary circuit and requires about 500 watts.

J. H. Cox: Mr. Gutzwiller has very ably discussed the advantages and disadvantages of mercury arc rectifiers for industrial applications. It should be realized that this is a tool considerably different from those electrical machines with which most electrical engineers are familiar. For this reason when any application is considered, the characteristics of the load and of the rectifier must be carefully considered. As Mr. Gutzwiller has pointed out the mercury arc rectifier has now reached a stage of development that provides entirely satisfactory reliability and there are many applications where its inherent advantages permit of no other kind of apparatus.

Mr. Gutzwiller has pointed out that since the rectifier has no fly-wheel effect the overloads which occur in main roll drive might cause objectionable disturbances on the a-c. supply system, if this system is of limited capacity. Another possibility of trouble, due to the same lack of fly-wheel effect, is that an a-c. outage at the wrong time might leave the rolls and material in an embarrassing position.

Mr. Gutzwiller mentions that the floor space requirements of the single tank unit were no more than that required by the rectifier itself, stating that any necessary repairs could be performed when the inside tank, or coverplate is raised vertically out of their containers. Although this procedure might be possible, I doubt if any operator would limit his apparatus and the room for making repairs to such close quarters.

Mr. Gutzwiller stated that graphite anodes were used by his company only in the larger capacity units where they were demanded by the more severe operating conditions, and that in the lower capacity units iron anodes were used because in such units operating conditions do not demand the use of graphite and the long de-gassing period required with graphite is objectionable. We have found that by pre-treating graphite anode electrodes in a high temperature vacuum furnace at 1500 to 1600 degrees centigrade before installing in a rectifier the de-gassing time is no longer than when iron is used.

In regard to injury caused by back-fire due to back currents from the d-c. bus, the modern high speed breaker disconnects the rectifier from the d-c. bus in so short a time that injury from this source is truly negligible.

A Member: I would like to ask Mr. Gutzwiller relative to the cost of these rectifiers?

W. E. Gutzwiller: The cost of 250 volt manually operated rectifiers is from 15-20 per cent higher than motor generators. The cost comparison is more favorable in the larger than in the smaller sizes.

R. E. S. Pope: All I have to say is to confirm the statements made by Mr. Gutzwiller and the Westinghouse Company. We have two 4000 amp. rectifiers in service nearly two years under very bad load conditions. We have a load frequently changing from zero to 10,000 amps., in 20 seconds, and the rectifiers have showed up very well under these conditions. A single unit has but one "backfire", the length of the "outage" was less than 30 seconds. One point I do not believe was mentioned—the absence of noise. Rectifiers are very silent in operation.

J. M. McTamney: I would like to ask if there are Mercury Arc Rectifiers in service operating in parallel with motor-generator sets and rotary converters closely connected on same feeders?

W. E. Gutzwiller: Rectifiers are successfully operated in parallel with motor generators and rotaries in a great many installations in this country. In some of these installations it has been necessary to slightly adjust the voltage characteristics by partly shunting the compound windings of motor generators and rotaries in order to obtain the desired parallel operation.

Reducing The Bearing Cost Per Ton Of Steel Rolled

By K. T. MacGILL
Engineering Representative, Jos. T. Ryerson & Son, Inc., Chicago, Ill.

Presented before Lubrication Engineering Division of the A. I. & S. E. E. at the Twenty-eighth Convention in Pittsburgh, Pa., June 23, 1932.

Whether times are good or bad, any change in operating conditions which will help to reduce the cost of the product manufactured is of definite interest to those who shoulder the responsibility for those costs.

The bearings in a steel mill, paper mill or any other piece of revolving machinery are the heart of the equipment. It is through them that the power to do the work must be transmitted; but these bearings are parasites, and they retain a considerable part of the power sent through them; and also in order to keep them operating smoothly, other costs must be incurred such as oil for lubricants and men to apply the oil. And, when they are out of order and must be changed, the cost of the change represents only a fraction of the loss that is entailed because production has stopped. This loss is directly chargeable to the bearings if the life of that bearing has been less than maximum.

There have been many effective steps taken to improve bearing conditions—by changing the design of the bearings; the materials used; and the lubricants for them; but it is only in ultra-modern machinery that all of these improvements have been combined, and their use has frequently meant a substantial increase in the cost of the equipment.

It would be very nice if every plant could throw out its old equipment and replace it with new; but unfortunately in most cases old equipment represents so much value that it cannot be discontinued—so steps taken to modernize this equipment by making it run smoother and longer and consume less power through its bearings will be steps forward worthy of consideration by this group.

The bearings in the older type of steel mills generally are either babbitt or bronze or a combination of the two. Both of these bearing materials are distinctly affected by heat; the babbitt in particular softens rapidly as the temperature rises. The heat in a roll neck or roll table bearing comes from two sources. First the roll itself and second the friction of the bearing. To control the roll heat, water is applied generously to the roll and roll neck; in fact so generously that to feel a bearing in operation means a shower bath.

To control the friction heat, lubricants are applied generously, usually so much so that approach to one of them with a good suit on means a trip to

the cleaners. Each of these cooling mediums are good, but unfortunately they don't harmonize and acting against each other sometimes the heat gets beyond control and checked necks and broken rolls are more frequent than the roller likes to remember.

Generally speaking, water is an absolute necessity at the rolls and it is obvious that if the water could be made to serve both—to dissipate the heat and effectively lubricate the bearing, it would reduce the operating cost of that part. With bronze or babbitt bearings, oil or grease cannot be dispensed with, but with the new bearing which I am glad to have the opportunity of telling you about will work best with water as a lubricant.

The fundamental requirements in a bearing are ability to withstand the crushing strains without cracking or splitting not only through the first 20% of the bearing thickness as installed, but through 90% of the thickness of the liner—the bearing must have a low coefficient of friction in order to consume a minimum of power; it must not cut or score the shaft under adverse conditions; it should give due and timely warning of trouble; and the bearing must not deteriorate either when in use or standing idle; and when it is necessary to change the bearing, it should be replaceable with a minimum amount of labor.

Let me explain the construction of this bearing material and how it conforms to these conditions.

The base of the bearing is layers of this specially woven heavy belting so constructed to combine the advantages of wear on the end grain of the fabric and the binding together of these end grains so that the bearing will hold together although worn down practically to the shell or chuck.

This strong belting is next thoroughly impregnated with a synthetic resin which has peculiar properties. In its primary stage, it looks like an ordinary piece of resin and is soluble and can be softened by the application of a moderate amount of heat. In this state, it is converted into a liquid by the proper solvents and the belting is thoroughly soaked in it. Then, after preliminary processing, the treated belting is placed in a large press under both, pressure and heat; and while there, the synthetic resin undergoes a transformation and is changed into a new product which is neither soluble or fusible. And the various layers of belting have been cemented into a homogeneous mass of the proper thickness and are for the finished bearing.

The belting untreated would have sustained very little load without deforming. The synthetic resin in its cured state while of great hardness would have been brittle and sustained little load; but these two factors combined have each cured the fault of the other and this finished bearing material will sustain a crushing strain of from 32,000 pounds to 36,000 pounds per square inch before breaking.

The permanent set of a piece of this material under 20,000 lbs. load per square inch is less than .0085" (eight and a half thousandths of an inch); on a high grade babbitt it would be between .070 to .100 (seventy to one hundred thousandths of an inch) tested under similar conditions. A piece of bearing bronze similarly tested showed a permanent set of .0113".

The material has sufficient elasticity to absorb shocks without cracking and still is so rigid that even in rolling very thin gauges of steel where the rolls are in contact with each other, there is no difficulty in holding gauge.

As to hardness this bearing material has a dual character; and while it will only Brinell between 30 and 40 under a 500 kilogram load, it will scleroscope about 70 to 85. A hardened tool holder bit scleroscopes about 60.

It is this characteristic of surface hardness which seems to give it its low coefficient of friction. One of the larger steel companies was interested in determining the coefficient of friction on our bearing with water lubrication as compared to a good grade of babbitt with an oil lubricant.

In their laboratory by means of a Timken testing machine, it was developed that:

Ryertex—Water Lubricated

under different loads ranging from heavy to light, developed a coefficient of friction with rubbing speeds of

550 ft. per minute from .0198 to .0075
425 ft. per minute from .0227 to .0160
280 ft. per minute from .0236 to .0175

BABBITT—Oil lubricated

415 ft. per minute from .0654 to .0705
280 ft. per minute from .0516 to .0678

BABBITT—Water lubricated

405 ft. per minute.....110

These figures show that between our bearing with water and babbitt with oil, the coefficient of friction of our bearing is about one-third of that of the babbitt oil lubricated and one-fifth of that of babbitt water lubricated. This last figure emphasizes the loss in power which results in a babbitt or bronze and babbitt bearing when the water dilutes the oil used for the lubricant.

A bronze or a babbitt metal is composed of a system of hard crystals embedded in a soft matrix. Properly lubricated these cushioned crystals carry the bearing load well; but under adverse conditions when the lubricant becomes thin or fails, these hard crystals tear at the shaft and as the heat rapidly increases, the softer matrix of the bearing recedes and the condition goes from bad to worse; and results in a badly scored shaft unless the machine is shut down promptly.

With our bearing material, there are no hard crystals to score the shaft and the worst that can happen under adverse conditions is a carbonizing of the surface fabric which will result in a more rapid wear. Furthermore, as this material is such a poor conductor of heat, only the immediate surface of the bearing is affected, and there is no complete break-down as would be in the case of a babbitt bearing. And, while this is taking place, the bearing will give off a pungent and distinctive odor at once calling attention of the operator.

Practically speaking, this bearing material is non-absorbent; the fabric is so completely impregnated with the resin that only the fibers on the immediate surface can retain any of the lubricating medium so that the bearing undergoes no change whether in service or standing idle as a spare.

The design of the bearing is also of importance. It is recommended that the radial and thrust collar

be separate units. It is seldom that the rate of wear on both, the thrust collar and radial shell portion is the same. By having them separate, the one wearing first can be replaced thus securing the maximum wear on both parts.

Of course, the actual test of a new product, is service. These bearings have been made in sizes ranging from 4" to 20" in diameter; thicknesses from ⅜" to 1", and have been tried in rod mills, bar mills, strip mills, plate mills, (cont. 96"), structural and blooming mills.

I believe that a description of some of these tests will go farther toward answering any questions you may have in mind than a further description of the bearing.

In a 10" Continuous Mill (Wurst) rolling small shapes, flats, rounds, and squares. Finishing stand. Size of neck 7". Speed 600-800 RPM. Service secured was 8 to 12 times that from a bronze and babbitt combination. Estimated power saving 15 to 20%. Depending on sections rolled, this job required 1½ to 2 thrusts for each radial—only water was used for a lubricant. No further trouble was had due to stalling motors.

Acme 10" Continuous Strip Mill—Bearings are in all stands and spindle carriers on this mill with a power saving being shown as high as 35%. This mill had contemplated the purchase of 300 additional HP, which was not necessary after the composition bearings were installed.

This mill had also tried some stands of roller bearings and stated that the power saving on this resinous type was comparable to that secured from roller bearings, particularly when consideration was given to the difference in bearing cost of the two types of bearings. To change rolls on the roller bearing stands required two hours and with the composition bearings about one-fourth of that time. No difficulty is experienced in holding gauge or rolling lighter gauges, or stalling motors.

10" Skelp Mill reports that the usual life of a brass was five to six turns. At four turns the composition bearing had only worn 1/32 of an inch. Further when they were running on brass, it was necessary to adjust the mill every 15 minutes; with the composition bearing, the mill was adjusted once per hour. All of these installations to which I am referring use only water for a lubricant. In this case the supply was 2-3/4 inch pipes.

28" Structural Mill, these bearings were for 18" necks. The speed was about 95 RPM. The mill was rolling structural shapes, I-beams, channels, and piling. Normal wear of the brasses was from 4,000 to 5,000 tons. At 6,000 tons the composition bearings had only worn 1/16 of an inch. And at that point it was estimated that the savings on lubrication was $28.00 and that the bearings were good for 10,000 more tons.

In a 28" Continuous Strip Mill Finishing Stand, Roll necks were 20" in diameter, 18" long, speed about 95 RPM, rolling gauges from .134 to .062 widths up to 27", based upon service to date bearings will roll from 100,000 to 120,000 tons or about 10 times the tonnage secured from the brass babbitt combination.

A power study taken over a month's period and compared with the other finishing stands in the same mill showed a 30% power saving. On this mill, each stand had its own drive, and on one occasion I watched the meters as the strip was going through. The one on the stand with these bearings showed 120 HP, while the others from 300 to 340 HP; and they were all doing their proper amount of work.

On a 36" blooming mill, 20" diameter neck, average speed 70 RPM. The test is at present incomplete due to intermittent operation, however, after rolling 30,000 tons, there was no appreciable wear on the bearing. I was present at one time when the rolls were being changed, and it was interesting to note that the neck carried by the composition bearing was only warm while on the opposite end which was running on brass, the neck was too hot to hold your hand on it.

This, I hope is an indication that the use of these bearings is going to mean freedom from scored necks, fire cracks, and broken rolls from this source; and probably will be a material help in dissipating the heat in the roll proper. Another thing, we learned on this test was that on a reversing mill, it is necessary that the bearing have a full contact in the chuck. On the first bearing tested, the liner was placed against a rough and irregular casting. The thought being that the great weight of the roll and pressure from the material between the rolls would dig into the bearing and form an additional lock. But, such was not the case. On the contrary, the high spots acted as skids or rollers and the whole burden of retaining the liner was placed upon the keepers. The bolts holding the keeper plate were not large enough and broke permitting the radial portion of the bearing to turn out of the chuck. It was indicative of the great strength of the material, however, that the 2" thrust collar carried the load and prevented the roll from dropping on the chuck and scoring the neck.

Another interesting application of this material was in a roll table bearing, directly in front of the furnace, serving a large plate mill. This bearing formerly was lubricated with oil and on account of the heat gave quite a bit of trouble. It is now lubricated with water and there is no apparent wear after two months of rather intermittent operation.

In reciting the successful results of trials of this material in different applications, I do not mean to infer that these composition bearings are universal in application regardless of the size or shape of the bearing. Nor that these bearings are automatically fool proof in operation. They do require watching when they are first installed to make sure the water supply is ample and getting into the bearing; but after the first run of satisfactory performance, they will continue to operate with practically no attention. We know that this mill type of a bearing covering the shaft from 70 to 160 degrees and cooled with water is satisfactory and efficient.

Depending upon the type of mill, it will save from 15 to 35% of the power formerly consumed in driving the mill. They will last from four to ten times the life of the old bronze or bronze babbitt bearings; and with this slower wear comes better accuracy in holding gauges and a consequent reduction in scrap.

On roll table bearings where water is available

for lubrication and cooling, they will show the same power saving and longer life as in the roll necks.

For closed or sleeve type of bearings where only oil may be used if high heat is a factor, it will probably need the development of a circulating oil supply in order that the heat may be dissipated. Special bearing problems will need special attention, and they will be worth it because in back of the problem will be the knowledge that here is a bearing material that is scientifically constructed to have great strength, maximum hardness, minimum coefficient of friction, low initial cost, and to return to the title of our paper its use in roll neck position in particular is actually showing power savings of from 15 to 35% with from four to ten times the life of ordinary bearings at a reasonable cost, thus automatically "reducing the bearing cost per ton of steel rolled."

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A. I. & S. E. E. Proposed Control Design Standards For D-C Steel Mill Auxiliaries

By E. L. UPP
Chairman, Special Magnetic Control Committee, and Electrical Supt., National Tube Company, McKeesport, Pa.

This standard covers control for D-C steel mill auxiliaries, i. e., those applications of control for machines used directly in processing steel.

Contactor Rating in Amperes

8 hr.	100	150	300	600
Mill	133	200	400	800
Operative overload Interrupting	400	600	1200	2400
Short circuit interrupting open panel	2000	3000	6000	12000
Short circuit interrupting enclosed	1000	1500	3000	6000
Mill H. P. Rating at 230 volts	35	55	110	225

8 Hour Rating of Contactors

The 8 Hr. rating of a magnetic contactor is its ampere carrying capacity for 8 hrs. under conditions of free ventilation with clean contact surfaces and with the wear allowance reduced to 20% of the original and not exceeding N.E.M.A. temperature limitations and with the operating coil circuit excited at full rated voltage.

Operative Overload Interrupting Performance of Contactors

A contactor shall successfully interrupt operative overloads of four times its 8 hr. rating with fifty operations at 10 second intervals. After such performance the contactor may be closed on load without inspection of tips, renewal of parts or the necessity of making any repairs.

Short Circuit Interrupting Rating

a. The short circuit interrupting rating of a contactor is based upon the maximum current at normal voltage that the contactor can interrupt under the CO-OCO duty cycle.

b. The value of the current shall be taken during the opening stroke at the instant arc voltage appears and shall be the peak value.

Short Circuit Interruption Duty Cycle

The standard interruption duty cycle shall consist of a CO-cycle where the breaker opens the circuit only followed after a two minute interval by an OCO cycle where the breaker closes the circuit followed immediately by its opening without purposely delayed action. (This is the so-called CO-OCO duty cycle.)

Short Circuit Interruption Performance of Contactors

a. At the end of a standard interrupting duty cycle at or within its interrupting rating the contactor shall be substantially the same mechanically as at the beginning although the tips may be considerably pitted. It is not to be inferred that the contactor may be reclosed on load after such performance without inspecting and, if necessary, renewing the tips. It should not be necessary to make any other repairs or renewals to put the contactor back into service.

b. An enclosed contactor shall perform at or within its interrupting rating without emitting flame from the enclosure.

Note: If the controller is enclosed the type and size of enclosure affects the interrupting rating of the controller. The enclosure shall be of such design and size that the controller will perform under the interrupting duty cycle without greater injury than specified in paragraph (a).

Test Load for Current Interrupting Rating

The contactor shall be tested with a non-inductive resistance load.

Coils

a. Coils for contactors and relays are to be furnished without protective series resistor wherever possible.

b. Resistor tubes where furnished to be stamped in ohms and watts or amp. as well as Manufacturer's identifying number.

c. Coils to be designed to close on 80% of normal voltage and stand 10% overvoltage without injury to the coil.

Classification of D-C Mill Auxiliary Magnetic Control

The standard types of D-C, mill auxilary magnetic control shall be as follows:

1. Non-reversing utilizing resistor class 55.
2. Non-reversing Dynamic braking resistor class 55.
3. Reversing, plugging, utilizing resistor class 53.
4. Reversing, Dynamic braking utilizing resistor class 55
5. Reversing, Plain utilizing resistor class 55.

Standard Number of Accelerating Contactors

The standard number of accelerating contactors in addition to contactor such as reversing, line, plugging shall be as follows:

Amperes Mill Rating	Number of Contactor for accelerating only
133	2
200	2
400	2
800	3* or 2*

* As specified by the user.

Standard Equipment of a Mill Auxiliary Controller

Each standard type of controller shall include:

1. DP main line knife switch with lockout device.
2. DP control circuit switch and fuses.
3. Automatic reset overload relays in each side of the line, these relays to provide instantaneous trip in each side of the line on overloads above 300% and time delay in at least one side of the line set to protect the motor on overloads below the instantaneous setting.
4. Undervoltage relay.
5. Negative line contactor.

Other Equipment of a Mill Auxillary Controller

1. Accelerating contactors in accordance with above standard.
2. Field accelerating relays or other means of field acceleration to be furnished only when specified.
3. Full field relays or equivalent means to be furnished on all control for adjustable speed motors where the range by field control is 1½ to 1 or above.
4. Field protective relays to be furnished for shunt motor control only. One relay to be connected in each side of the shunt field.
5. Field discharge resistors to be connected permanently across shunt field.

Framework for Supporting Controller

1. Angle iron framework to be standard.
2. The minimum size of angle iron will be 1½ x 2½ x ¼ or 1½ x 2¼ x 3/16 inches.
3. Angle iron framework shall be 76 inches high.

Base Material

The base material to be mfg. choice of either compound material or Monson slate unless otherwise specified. The minimum thickness of base to be 1".

Construction of Controllers

1. Layout of devices on the controller

a. The layout of the contactors and main line switch to be such that the resistor outgoing terminals to be located on the top portion of the panel the line terminals on the center portion of the panel and motor terminal on the bottom portion of the of the panel. Where the line switch is not included on the panel the line terminals to be on the bottom portion of the panel.

b. The control terminal board to be at least 18" from the bottom of the vertical angle and mounted on the right hand side, back view.

2. Panel Wiring

The control wires on a panel to be connected to the stud shown on the wiring diagram. The wire need not follow the same location on the panel as shown on the wiring diagram.

3. Spacing from floor

Panels shall be so constructed that in no case will there be less than 6" from the bottom of the base to the bottom of the angle iron framework.

4. Spacing of panel from angle frame

The distance from the front of the base to the front face of the angle frame support shall be 1¾" for all D-C auxiliary panels.

Safety Features for Metal Mixing and Similar Hazardous Operations

1. Protection against running in the same direction when master switch or pilot device is reversed and reversing contactors freeze.
2. Control circuit to two separate control devices must be opened by the master switch. The control devices to be connected in each side of the line to insure interruption of the power circuit in case of a ground.

Enclosures

1. The minimum thickness of material for standard enclosures shall conform to Underwriters' Laboratories' Standards. (Industrial Control).
2. The enclosure shall include swinging or hinged doors on the front and removable back. The door swing shall not exceed 28".
3. Enclosures shall be of moisture resistant construction. The finishing coating to be mfg. choice unless otherwise specified.

Wiring Diagrams

1. The size of wiring diagrams shall fit into the following classes:
   a. Letter size.
   b. Two times letter size.
   c. Four times letter size.
   d. Eight times letter size.
2. Each wiring diagram to include a sequence table of the device operations.
3. A definite distinction to be made in the size of lines indicating control and power circuits.

4. Cabling of wires from panel to master switches, limit switches, etc. is required to eliminate parallelling of wires.
5. Wiring diagrams furnished on an order shall be properly labeled as to manufacturers' order, manufacturers' number, item number, etc. A sticker or stamping on the back of the blueprint is satisfactory.
6. Dimension prints to be separate from the wiring diagrams.
7. The schematic circuit diagram to be shown on the panel wiring diagram up to and including drawings of 8 times letter size. Above this size it will be optional with the manufacturer whether the schematic will be shown separate. In case it is shown separate adequate cross reference numbers must be used.
8. Devices to be shown on the wiring diagram in their relative location on the panel.
9. Terminal markings on the back of the panel to be the same as on the diagram. Device markings to be stamped on the front of the board and agree with the wiring diagram. Stenciling is considered satisfactory.
10. Wiring Diagram to be back view.
11. Resistor information to be on the wiring diagram or the resistor diagram to be adequately cross-referenced with the wiring diagram.

Wiring Symbols and Terminology

Symbols and terminology to be in accordance with N.E.M.A. Standards.

Marking of Shipments

Crates should be marked with customer's item number, order number, specification number and with manufacturers' order number. Multiple shipments must have each item number specified in the crate in which they are included.

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DISCUSSION

Roll Neck Lubricants and Lubrication*

By W. D. HODSON,
President, The Hodson Corporation,
Chicago, Ill.

Presented before the Lubrication Engineering Division of the A. I. & S. E. E. at the Twenty-eighth Convention in Pittsburgh, June 23, 1932.

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DISCUSSION PRESENTED

By P. G. LESSMANN
Power Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

The paper that Mr. Hodson has read here gives a very complete picture of the present status of mill neck bearings, not only with respect to lubricants and lubrication, but also with respect to their practical operation in general. There are a few facts regarding the present status of mill neck bearing operation which seem to be outstanding.

First, wear. Sometimes excessive wear of bearings is a common occurrence, hence there is a permanent set up in the Operating Department for spare bearings, their rapid replacement and inclusion of such items in the operating expense.

Second, many remedies are proposed, such as trying out different kinds of lubricants or different bearing metals, or the change from sleeve bearings to anti-friction bearings or, last but not least, installation of some kind of automatic or continuously operating oil feed and circulating systems.

Third, relatively little is said about the actual causes of all bearing difficulties. This, of course, is a matter of applied theoretical physics, and should have first consideration.

In the matter of sleeve bearings, this much must be said: Wear or excessive wear on a sleeve bearing is failure of the bearing. Sleeve bearings fail if the lubrication fails. The lubrication fails (1) if the lubricant does not enter or is not fed properly into the bearing, (2) if the lubricant film cannot be established. This again may come about by excessive bearing pressure or by an extremely low surface speed or by the use of a lubricant which cannot form an oil film, i. e. if the viscosity is too low. In this connection, it can be mentioned that hard greases have their range of speeds and pressures at which they will best operate, and that machine oils have their proper field. Both may at times overlap. (3) Lubrication fails if an oil film once established cannot be maintained. This may come about by roughness of the surfaces, or by the entrance of foreign matter into the bearing, which breaks up the oil film. Foreign matter in this connection means also water in an oil lubricated bearing or vice versa, or generally any liquid other than the lubricant which has a viscosity considerably different from the one of the lubricant used, or an oil film once established might not be maintained if the bearing is heated excessively, i. e. to a temperature at which the viscosity of the lubricant becomes such that it no longer can form a lubricant film.

All of the causes for failure mentioned are present in mill neck operation, some more, some less. It is their entire elimination that will free the operator from his bearing worries.

The first group of causes for failure mentioned requires to cut out manual lubrication and substitute

*Paper appeared in the June, 1932, issue of the Iron and Steel Engineer.

automatic lubrication of some form with a commensurate design of the mill neck bearing.

The second group of causes for bearing failure requires a careful analysis of the application of the bearing on the side of the mill designer.

The third group of causes requires a design carefully planned on the basis of full co-operation of the operator in keeping his bearings in shape.

Some mill builders have recognized these outstanding facts and brought forth designs of sleeve bearings which were carefully planned for their application. The anti-friction bearing industry has done its share in offering a substitute for the dreaded sleeve bearing. The mill operators have begun to make lubrication automatic on a large scale—all with equal success. But the tendency of all three of these is toward enclosing the bearing so that no foreign matter, especially no water, can enter the bearing from the mill, which is very detrimental to both anti-friction and oil lubricated sleeve bearings. Besides these developments, there is the micarta bearing of the Westinghouse E. & M. Co., about which you will hear during this Convention. This bearing needs no protection against water especially; in the contrary, it operates on water. If oil also is used on it, it may help to reduce the friction. I might even go so far as to say that if oil should ever get into it, it will do no "harm".

In concluding, I wish to call attention to the fact that the builders of electrical machines have been for a long time called upon to furnish machines whose bearings do never fail, do not leak oil, have no oil consumption to speak of, require the least amount of attention during operation, and show low power losses. I am hopeful to see the day when the same can be said of mill neck bearings.

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DISCUSSION

Care and Maintenance of Instruments Used In The Steel Industry*

By MARTIN J. CONWAY,
Fuel Engineer, Lukens Steel Company, Coatesville, Pa., and
R. C. KENNAN,
Manager of Service Department, Brown Instrument Company, Philadelphia, Pa.

Presented before the Combustion Engineering Division of the A. I. & S. E. E. at the Twenty-eighth Convention in Pittsburgh, June 22, 1932.

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Discussion Presented by

M. J. Bradley, Engineer, Leeds & Northrup Company, Philadelphia, Pa.

W. G. Walker, Efficiency Engineer, Carnegie Steel Company, Clairton, Pa.

H. Dobrin, Consulting Fuel Engineer, Pittsburgh, Pa.

J. M. Whitten, Engineer, Brown Instrument Company, Philadelphia, Pa.

M. J. Bradley: Mr. Chairman and gentlemen, I might make a few comments on the paper. We are heartily in accord with the proposed outline of procedures as listed in the paper. We feel that the authors deserve to be complimented on initiating a program which will be beneficial to the steel industry as well as to the instrument manufacturer. It has been our experience that, in plants where all the pyrometric equipment has been the direct responsibility of one department, more efficient service has been obtained from the equipment and the results have been more satisfactory to the user. We like to see the responsibility for the equipment placed in one department so that quicker results may be obtained in case of anything going wrong with the equipment.

We feel that more detailed attention could be given to the selection and application of the instrument for typical installations, such as in the open hearth department or on reheating furnaces or on soaking pits and so forth. Occasionally one encounters an installation where the user seriously questions the benefits of the records obtained. But after the problem has been analyzed and compared with the results the user wished to obtain, it is apparent that the fault is not in the instrument but in the application of its functions or in the location of the thermocouple or measuring element. That is, there are chances for misapplication.

Obviously, a record obtained during the first steps in the processing of the steel is more valuable as an operating guide, both for the rolling process or for the furnace operation, than a record obtained after the rail has passed through the finishing stand. Equipment is now available to accurately record the temperatures during the third or fourth pass or just after the scale has been removed from the metal, without slowing up production, even though the time available is only three or four seconds.

We feel that the person in charge of the Instrument Department should be familiar with the capabilities of the various instruments and, also, so well

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versed in the process under consideration that instruments will not be installed to obtain results which are beyond the possibility of that instrument. In fact, it seems that the instrument man should devote considerable of his time and effort in co-operating with the superintendents of the various departments in order to solve the problems relating to operation for efficiency. He ought not to be so busy checking and repairing instruments in order to keep them going that he is wanted in several departments at the same time. This leaves the instrument man open to unjust criticism and limits his usefulness.

During the last few years, instruments have been designed to meet the severe conditions under which they are called on to work in the steel mills. For instance, cases are provided that are dust and vapor proof, and recording instruments have been designed so that the slight wear that might take place during the operation is compensated for so that it does not cause any error in the measurement. One outstanding development, which relieves the instrument man from the necessity of balancing frequently the standard cell on potentiometers, is the automatic standardizer which checks the measuring circuit approximately every forty-five minutes. That assures the instrument man that the measuring circuit is correct even though he becomes tied up in one department of the plant to such an extent that it is impossible for him to visit potentiometers in other parts of the plant for several days.

In other words, the instrument man, perhaps, is better qualified than anyone else to educate the operators in how to use the results of the instruments so that they will benefit them during the process of operation. In that way the operator can get the use of the instrument and improve conditions. We like to see the instrument so located that it is available for the operator during operation as well as a recorder for the detail department afterwards. Thus, if you can get the operator interested in the instrument and what it is trying to do for him, he will find that it is co-operating with him and working to his advantage, and he is more anxious to see it in operation. In other words, we feel that the instrument man can do very valuable work in co-operating with the operators and teaching them how to use the information given by the instrument to their advantage, and thus show them what changes to make during the process, rather than have the instrument act as a recorder of their shortcomings later on. Perhaps he could be more valuable in that capacity than in constantly checking up and taking care of instruments to see that they run.

We feel that by proper application and selection of instruments the time necessary for maintenance will be greatly cut down and that the instrument man will actually have a chance to study processes and be a real efficiency unit, possibly, in the operating department. In other words, if an instrument is being considered for a certain application, we feel that the initial cost, possibly, is being overemphasized, whereas the important considerations should be the maintenance and the steady operation of the instrument; because, if the personnel depends upon the record of the instrument and it fails to function, why that means considerably more in loss and inconvenience to the personnel.

After having once made an investment in equipment, the information which it gives should be used intelligently and recorded in order to make the most use of the equipment in bringing about improvements in the quality of product and savings by more careful control.

The information given by recorders is valuable if used properly. The records should be removed daily and filed for reference purposes.

It is very disheartening to the instrument manufacturer to find instruments, which have been carefully designed after years of research, not being taken care of and the information which they give not being used to full advantage.

I think the paper is an excellent method of getting this subject before the steel industry and getting a more uniform action and application of instruments.

W. G. Walker: I feel that often the work of the instrument department can be reduced by more regard for standardization. In many cases it will be found that there are several ranges or styles of instruments in use where one would be sufficient. For example, one thermometer may have a range of 0 to 160 degrees while another will have a range of 0 to 170 degrees. Since the working range is usually kept well below the maximum range of an instrument there is no reason why either range could not be used for both instruments. The same reasoning applies to the instrument connection, whether top, bottom or back, and to the style of case, mounting, etc. If the instruments are not standardized, a spare must be carried for every different style in operation, if continuity of record is to be insured. This in turn means a considerable investment for instruments that are idle most of the time. It also means extra storage, more charts to be carried, and more difficulty in making replacements.

In one case called to my attention, a list of 110 indicating pressure gages included six different dial sizes and sixteen different ranges. By standardizing it was possible to carry only one dial size and six ranges. The number of spares necessary was reduced and replacements are always possible, a condition that did not exist previously.

From my own experience it seems that these conditions exist at least partly due to a lack of co-operation between the different instrument companies and their customers upon this subject. While I do not mean to place the entire blame on the instrument companies I do feel that they can assist in the selection of instruments to a greater extent than they do. Especially is this true in the case of new installations as once the instruments are installed standardization becomes very difficult. Standardization of instruments, as with any other equipment, reacts to the advantage of both the manufacturer and the user by making possible repairs and replacements at a minimum of cost.

H. Dobrin: I can't help making one brief remark —how times change! In this paper there is an outline of all the facilities that people should have in

their plants and you talk of special service men to take care of instruments and the spares that you ought to have. I remember some fifteen years ago it was almost impossible to induce a plant to put in even a portable type indicating pyrometer. I happen to remember in 1917 when a certain indicating instrument was sold in Chattanooga, Tennessee. It was such an important event that the secretary of that company, himself,—and that company is now a very great company,—came to be present at the ceremony when that instrument was installed. And I remember that evening there was a party in the plant and they served sandwiches to the men, because an instrument was installed which showed the temperature in the glass tank. Today people will spend more money for a dust-proof case to protect the instrument than it was possible for them to imagine they would ever want to spend for the entire instrument. Of course, we all know there's been a great amount of progress and there's been a great deal of appreciation on the part of all industries that employ heat of the great value of an instrument which will indicate or control temperature.

J. M. Whitten: I have very little to add in closing except that I do think the paper gotten together by Mr. Conway and Mr. Kennan certainly brings the matter of instrument making and the care and selection of instruments to a place where its importance duly warrants that it should be. And I think it will occupy an even more important place in the future, as I look around here and see the faces of the many men whom I meet in plants and know how well some of them have their instrument departments organized.

I think there is a great deal more to be done; but, with more money being granted for the instrument department, for materials and for places for the men to work, it is very gratifying to one who has worked in the instrument business for some time to see it grow—although my experience doesn't date back to Mr. Dobrin's but back to only a few years ago when the condition was only a little improved over what he mentioned.

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Higher Steam Pressures In The Blast Furnace—Steel Mill Power Plant

By
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and
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Presented before Combustion Engineering Division of the A. I. & S. E. E. at the Twenty-eighth Convention in Pittsburgh, June 22, 1932.

The average pressure at which steam is used for power production in public utility plants has undergone a marked increase in the last few years. In 1920, 250 pounds per square inch or thereabouts was regarded as a standard, while today the average is in the neighborhood of 450 pounds. Many plants have been built for higher pressures, particularly in the range 1200-1400 pounds, and some more or less experimental plants are operating with boiler pressures at or near the critical pressure of 3226 pounds. The practice as to superheat and total temperature of the steam has also changed. 600 to 650°F was considered a conservative high temperature, while today the practice ranges from 750 to 850° and 1000° is thought to be quite within the future possibilities.

How far should the blast furnace-steel mill go in adopting these higher steam pressures and temperatures? A few steel mill power plants have been built for pressures of four to five hundred pounds and are producing most satisfactory results. But there is still much uncertainty among steel mill executives and engineers as to whether these higher pressures are suitable, particularly for the blast furnace gas fired power plant. It is the purpose of this article to set forth as simply as possible the true situation as to higher pressures and temperatures in the blast furnace-steel mill steam power plant.

The economics of fuel utilization for the production of steam and power for steel mill use is not fundamentally different from that for a public utility. The steam power plant in a blast furnace-steel plant is a unit for the conversion of the heat in fuel into power or its introduction into steam. Its economy is a function of the quantity of steam and power that can be produced for a given money value in fuel and fixed charges. The public utility plants economy is identical; only the scale of values is different.

Blast furnace gas has been regarded as a fuel which, if not used under boilers or in hot blast stoves, must be wasted. In recent years, however, the forward looking steel mill engineers and executives have been making every effort to use it for other heating purposes. In its natural state it is a suitable fuel for underfiring coke ovens, soaking pits and some other miscellaneous uses. Enriched with suitable amounts of coke oven or other rich gas it is suitable for any of the heating or melting processes in the steel mill. Instead of its value being equivalent to the amount of steam coal it would replace, it must now be regarded as equivalent to the amount of gas producer fuel, operating cost and fixed charges that it can replace.

It is true that in many mills it is not at present practical to use blast furnace gas for general metallurgical purposes because the changes in coke ovens, furnaces, etc. would be too costly. However, as time goes on it will become more and more necessary in all plants to increase the economy in the use of fuels, in order to meet competition. For this reason, new power developments should not be designed for relatively uneconomical steam conditions as such a procedure would militate against the realization of economies in the use of fuels later on when conditions warrant making the necessary changes.

The economy of the steam cycle improves with increase in pressure right up to the critical pressure of 3226 pounds per square inch, being greatest per unit of pressure increase at the lower pressures. Up to about 550 pounds per square inch equipment, piping and valves have been in regular use long enough to put these pressures in the same category as to operating safety and simplicity as 200 pounds.

Probably the most serious deterioration that takes place in a steam turbine is blade erosion due to the presence of moisture in the steam. By using steam at a sufficiently high superheat the turbine exhaust steam may be made dry, thus eliminating all moisture from the steam passing through the blading. However, there are practical limitations on the temperatures which can be used with materials and designs now available. The present day practice is, broadly to use a superheat for any given pressure that will produce not more than about 10% moisture in the exhaust steam. For fairly large turbines, say 20,000 Kw. or larger, this end is accomplished approximately with the following superheats for the pressures stated:

TABLE I

Gauge Pressure	Superheat Degrees F.	Total Temperature Degrees F.
250	260	665
350	290	726
450	313	767
550	331	805
650	347	843

These values are based on an expansion to a vacuum of 29 inches.

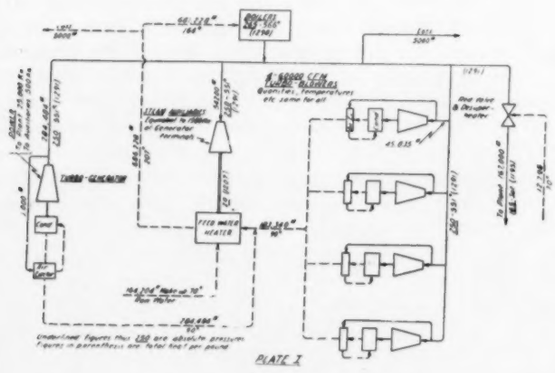

FIG. 1.

With materials now available and with which there has been a fair amount of experience the conservative limit of steam temperature is about 850°F. If this is taken as the temperature limit the economic limit of pressure for a continuous expansion cycle is about 650 pounds per square inch. It is possible, as has been done in a number of public utility installations, to remove the steam from the turbine and resuperheat it before it has expanded to a pressure where moisture is formed. It may then be reintroduced into the turbine and the expansion to vacuum completed without the formation of moisture beyond the economical limit. This practice, however, involves additional equipment, a considerable increase in complexity and does not ordinarily produce a return of a magnitude that would be attractive in an industrial power plant.

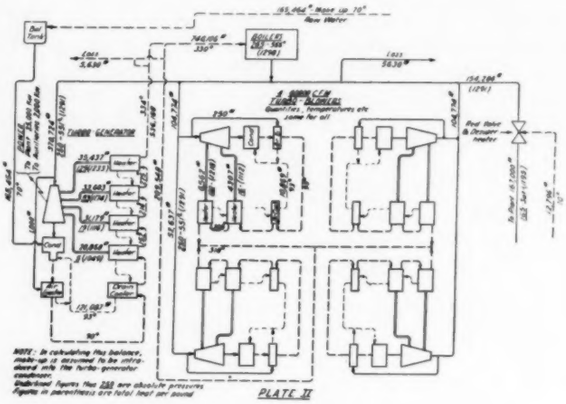

FIG. 2.

Steam turbines for a maximum steam temperature of 750° are no more costly for 450 pounds pressure than for 250. This is in part due to the fact that the steam volumes are less and the passages, therefore, smaller which compensates for the increased thickness of metal. If the steam temperature is higher than 750° the higher pressure turbine will cost more. All the factors lead to the conclusion that in the present state of development a pressure in the neigborhood of 450 pounds per square inch is a conservative maximum for use in the blast furnace-steel mill power plant. There might be instances in which, due to local conditions, a higher steam pressure and temperature would be justified and any new installation should be studied by engineers competent to determine the true economics for the particular case.

In order to show the relative values of different pressures practical heat balances are shown for a blast furnace-steel plant power and steam system with different pressures, temperatures and types of heat cycle and are given herewith. The fundamental data used for all cases are as follows:

Electrical energy required	25,000 Kw.
Blast furnace blowing at 20 # per square inch	240,000 c. f. m.
Steam required for miscellaneous uses outside the power plant assumed in all cases to be delivered at 150# per square inch gauge	167,000# per hr.
Power for driving power and blowing plant auxiliaries equivalent to an output at generator terminals of	2,000 Kw.
Vacuum in all condensers	28½"

Fig. 1. This diagram shows a plant operated

with 235 pounds gauge pressure and 150° superheat at the turbine throttles. The cycle is non-regenerative feed water being heated with the exhaust from steam driven auxiliaries. There are many plants operating with these steam conditions though the moisture present in the turbine exhaust (about 12½%) is somewhat high.

The steam for miscellaneous plant uses is supplied by desuperheating and reducing the pressure of boiler steam. The temperature difference between 235 and 150 pounds pressure is 35° F. which is rather low for an evaporator. This plant would therefore use treated water for all makeup except in a case where the water supply was exceptionally bad. It is assumed that 500 Kw. of electrical energy is supplied for driving part of the auxiliaries, the balance being steam driven.

Fig. 2. This diagram shows a plant with the same steam conditions as Fig. 1. In this case, however, a regenerative feed water heating system is used and all auxiliaries are motor driven. It is the practice in plants of this class, when auxiliaries are motor driven to provide steam driven spares for certain of the important auxiliaries for use in emergencies.

Fig. 3. This shows a plant using a throttle pressure of 235 pounds but with a steam temperature of 750° F. or 354° superheat. It is shown to indicate the gain possible by increasing steam temperature without increasing pressure.

Fig. 4. This shows a plant with regenerative cycle using a throttle pressure of 435 pounds gauge, 750° total temperature and using an evaporator for the supply of miscellaneous steam at 150 pounds gauge.

Fig. 5. As explained at some length below, there are many cases where treated water may successfully be used for boiler feed and a turbine can be used as a reducing valve. This diagram shows such a cycle.

The following table summarized the principal quantities involved in the several systems shown:

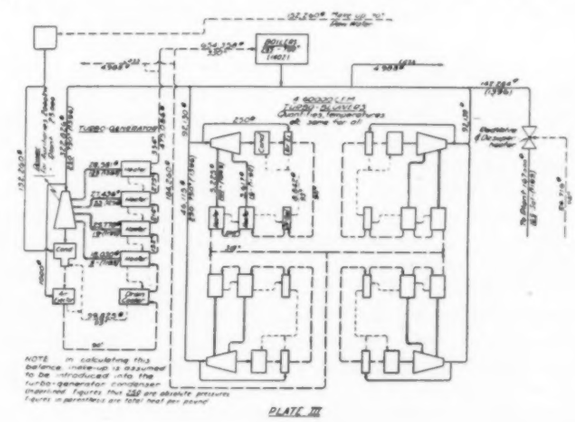

PLATE III

FIG. 3.

TABLE II.

			Total Steam Generated Pounds per hour.	Total Heat Added to Feed Water in Boilers Millions b.t.u. per hour.
I	250# abs.-150°	Non-regenerative	681,228	765
II	250# abs.-150°	Regenerative	740,106	738
III	250# abs.-750°	Total Temperature Regenerative	654,358	721
IV	450# abs.-750°	Total Temperature Regenerative w. Evaporator	685,558	698
V	450# abs.-750°	Total Temperature Regenerative with Red. Turb.	619,756	646

These diagrams demonstrate clearly first the advantage of the regenerative cycle; second, the advantage of higher pressure; and third, the advantage of the non-condensing turbine used as a reducing valve.

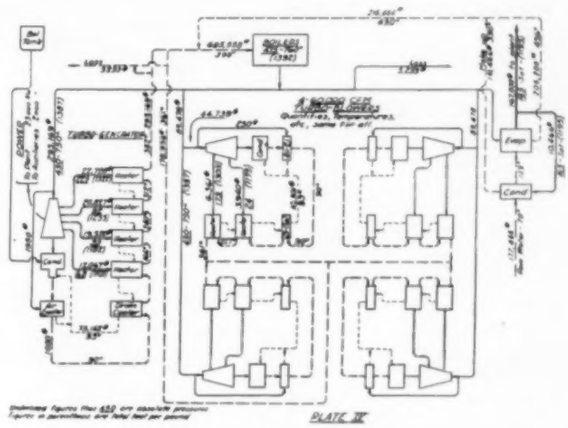

PLATE IV

FIG. 4.

The cost of the 450-550 pound plant is little if any greater than that of the 250 pound. The cost of the boilers per unit of capacity is higher for the higher pressure but the boiler capacity required is less for the higher pressure.

Assuming that boilers will be operated at 300% of rating in all cases, the boiler surface required, without allowance for spare capacity, will be as shown in Table III.

The boiler units may then be smaller for the higher pressures which will permit the use of a smaller building. The difference between I and V, for instance, would allow a reduction in size of boilers of 24%.

Steam piping must, of course, be heavier for the higher pressure but here the physical properties of the steam tend to offset the effect of the greater thickness of pipe. One pound of steam at 250

TABLE III

	Abs. Press.	Total Temp.	Type of Cycle	Work Done by Boilers	Work Done by Superheaters	Boiler Surface Required at 300%
I	250	550°	Non-Regen.	699×10^6	65×10^6	69,600 sq. ft.
II	250	550°	Regen.	667×10^6	72×10^6	66,300 sq. ft.
III	250	750°	Regen.	590×10^6	129×10^6	58,700 sq. ft.
IV	450	750°	Regen. & Evap.	569×10^6	129×10^6	56,600 sq. ft.
V	450	750°	Reg. & N. C. Turb.	530×10^6	116×10^6	52,700 sq. ft.

pounds abs. and 150° superheat has a volume of 2.288 cu. ft. while at 450 pounds abs. and 750° total temperature the volume of one pound is 1.53 cu. ft. This represents a reduction in area of the pipe required of 33%. As an illustration, take the steam quantities required for I and V and assume that a velocity of 10,000 ft. per minute is to be used in both instances. In I a 22" pipe would be required and only a 16" in V. This difference in pipe size applies to valves, fittings, hangers, etc. and not only does it tend to reduce the amount of pipe material but also simplifies the installation of the piping because of the smaller sizes to be located.

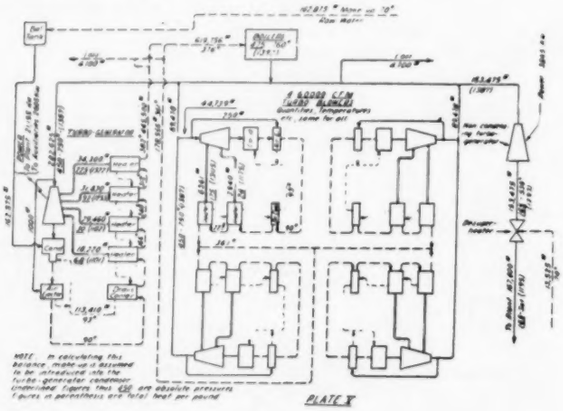

FIG. 5.

A review of the principal items entering into the cost of a steam power plant shows what a small proportion of them are influenced by the steam pressure used.

The costs of the following items are not affected by steam pressure within the limits under discussion:

Land.
Building for turbines and turbo-blowers.
Miscellaneous building service facilities, lighting, sanitary equipment, elevators, heating, etc.
Turbo-generators.
Turbo-blowers.
Electrical switchboards, wiring, transformers, etc.

The cost of the following items might, because of better economy, be reduced by the use of a higher pressure:

Boiler House building.
Solid fuel storage, handling and burning systems.
Blast furnace gas piping, burners, etc.
Boiler supports, settings and draft system.
Ash handling system.
Condenser.
Circulating water piping and pumps.

The cost of the following items is increased for the higher pressure:

Boilers.
Steam piping and valves.
Boiler feed water piping and valves.
Boiler feed pumps.
Closed feed water heaters.
Water treating.

The items of increased cost brought about by the use of the higher steam pressure are few and constitute a relatively small proportion of the total plant cost. Conditions peculiar to a specific installation will, to some extent, influence the cost and no hard and fast statement can be made as to the relative costs for the pressures under discussion. It must be apparent, however, that the cost for the higher pressure would be little, if any, greater than for the lower.

Experience has shown that the installation of air preheaters for reclaiming heat from the boiler flue gases is usually profitable. It has also been found that the preheaters should be proportioned so that under no ordinary conditions of operation will the exit gases be reduced to a temperature below their dew point. This tends to bring the exit gas temperatures to a fixed minimum. The efficiency of boiler and air heater will be substantially the same regardless of pressure.

The regenerative feed water heating cycle has become almost a standard practice in steam power plant design. The chief reason for its use is its increased economy over the practice of heating with exhaust from steam auxiliaries. A second and nearly as important reason is its greater simplicity. It automatically maintains the feed water temperature at a maximum practical value for all conditions of load. There is never either an excess or deficiency of steam for feed water heating. To secure the full advantage of this system, auxiliaries must be motor driven. This eliminates auxiliary steam and exhaust piping except such as is required for emergency steam driven vital elements. Control, when auxiliaries are motor driven, is much more satisfactory than when they are driven with steam. The cost of a complete regenerative system including motor drives, wiring, control, etc. is usually found to be less than that of a complete non-regenerative system including steam drives, piping, valves, drip system, etc.

The fact that considerable quantities of steam at moderate pressures are required in a steel mill for miscellaneous uses is not of sufficient consequence to penalize the entire plant efficiency. These miscellaneous steam uses are rapidly decreasing and as steel plants are improved will become less and less important.

If the initial steam pressure is reasonably high, steam for miscellaneous distribution through the plant may be supplied by an evaporator plant or through a non-condensing turbine exhausting at the pressure desired for distribution. The choice between the two methods will depend upon the quality of water available for boiler feed purposes.

Because of recent improvements in methods of feed water treatment it is no longer considered necessary to provide distilled water for boilers operating with pressures up to 500 or 600 pounds per square inch. Clean feed water is, of course, desirable in any steam plant regardless of steam pressure. However, the use of an evaporator where considerable quantities of process steam are required results in a considerable loss in economy as evidenced by the difference between IV and V in Table 2. It is therefore a question for analysis in each instance to determine whether, under existing conditions, an evaporator plant is most suitable.

Operation at high rates of steam production permits a great saving in first cost of plant. Assume a boiler plant to produce 750,000 pounds of steam per hour. At 150% rating, this will require approxi-

mately 17,000 boiler horse power. At 300% rating, only about 8,500 boiler horse power will be required. At $200. per installed boiler horse power, this would represent a saving in first cost of $1,700,000. For this reason, present day plants are designed to operate at as high ratings as practical considerations will permit.

In practically all plants having a varying load the highest loads only last for a short time. In one of the large steel mills in this country the maximum steam demand is about 1,225,000 pounds of steam per hour. But the steam demand exceeds 1,080,000 pounds per hour for only about 500 hours during the entire year. The average demand for this plant is about 900,000 pounds per hour. About 80% of the total steam produced is at rates between 600,000 and 1,080,000 pounds per hour. The boiler plant should be designed to give a good practical efficiency at steaming rates between these last mentioned limits. For the high peaks the rating may be permitted to run up to relatively high values with, of course, some sacrifice of efficiency.

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DISCUSSION

Discussion Presented By

H. J. Kerr, Engineer, Babcock & Wilcox, Inc., New York, N. Y.
E. A. Brown, Jr., Asst. to Chief Mechanical Engineer, Carnegie Steel Co., Homestead Works, Munhall, Pa.
J. L. Miller, Steam Engineer, Carnegie Steel Company, Youngstown, Ohio.
O. P. Adams, Steam Engineer, National Tube Company, McKeesport, Pa.
C. W. E. Clarke, Consulting Engineer, United Engineers & Constructors, Inc., Philadelphia, Pa.
J. S. Fulton, Special Representative, Ingersoll-Rand, Inc., Pittsburgh, Pa.

H. J. Kerr: I would like to compliment Mr. Clarke on his paper. I might add that so far as I can see, experience in central station work certainly proves that 1400 pounds, or any pressure approaching that, at temperatures up to 850 degrees represents no operating problems that are not easily solved and easily taken care of.

E. A. Brown, Jr.: Mr. Chairman, I'd like to ask a question. I wonder if Mr. Clarke could offer anything regarding his study of pressures for waste heat boiler work where we have to admit the greater economies of high pressure generation on turbines but at the same time have also to consider the higher steam temperatures in boiler absorption due to the low temperature differential and consequently lower economies.

J. L. Miller: I would like to ask a question. What is the relative installation capacity desirable when considering boilers installed for raw boiler water over boilers installed for treated boiler water? What are temperature and pressure limitations relative to raw boiler feed, if any?

O. P. Adams: I'd like to congratulate Mr. Clarke on the very interesting way he handled his subject and would like to have him discuss, a little at any rate, the application of the bleeder type of turbine with a high pressure cycle and bleeding steam at the general mill pressure.

C. W. E. Clarke: In answer to Mr. Brown, this waste heat problem is quite annoying in some of our thermal analyses. For practical consideration, 250 to 275 pounds is about as high as you can go and get very much return unless you use a two-stage type of boiler, as the temperature difference available becomes limited as the saturated steam temperature rises. I have found a number of cases where, it was quite annoying to find this waste heat problem in the picture, as it upsets a logical solution of the problem but the best disposition you can make is to have your waste heat serve for your auxiliary low pressure steam and float it on the line. It naturally cuts down your generation available due to rejected steam if you have a non-condensing turbine between your high pressure and low pressure system as your reducing valve. But the problem has to be met and provided for. I have found some instances where the waste heat problem was large enough so that it was possible and it paid to put in a low pressure generating plant using the steam from that waste heat plant alone, thus not involving the general plant high pressure steam system.

In reference to Mr. Miller's question as to spare capacity in a treated water versus non-treated water plant, this is a pretty hard question to answer off hand. The general theory of spare capacity is to have enough capacity to run you when you have to take a unit out. That means you have to relay your largest unit whether it be boiler or turbine. It applies to everything in your plant that requires maintenance. Some types of raw water plants would require very much more spare boiler capacity than treated water, and some types of treated water plants require more capacity than raw water, due to more frequent outages. I don't think you can make a general statement; but, knowing the condition of water and the method of treatment, I believe it can be treated logically and safely.

I don't know that I understand Mr. Adam's question on bleeder turbines. I'll answer it as I think it was intended and let him tell me if it's what he wants. It is entirely possible, of course, to bleed a relatively large amount of steam out of any specially designed turbine at any pressure. It is also possible to bleed out of a 400-pound turbine at 60 pounds, 40 pounds, and so forth, and there is a place for this kind of machine, especially in chemical plants, but in most steel plants the requirements of steam in volume makes it inadvisable. It probably is better to put a non-condensing turbine across the line and use it as a reducing valve. Does that answer your question, Mr. Adams?

O. P. Adams: The reason I asked that question is that any study of power equipment has to be

based on, we'll say, some twenty years' estimate of what your mill's steam demand is going to be. We don't know at the present time just how far electrification is going to go. In other words, if we build a plant for 600,000 pounds, we may have a mill demand twenty years from that of 600,000 pounds or 150,000, and the straight reducing valve turbine might find itself in a position where no use could be found for the full amount of its exhaust.

C. W. E. Clarke: All you have to do in that case, Mr. Adams, is put this reducing valve across your line and, as your requirement of low pressure steam drops, put in a condensing turbine and run from 150 pounds down.

O. P. Adams: Provided you're willing to assume the expense of this additional unit.

J. S. Fulton: I just want to inject a thought along the lines of Mr. Clarke's paper. He has shown the advantages of expanding the 450# steam through a turbine, thus supplying steam for the 150# line and at the same time generating power, as a by-product, to drive the blast furnace blower. So long as the 150# steam demand is constant, the reclaimed power remains a by-product, but once the demand for 150# steam decreases below that required to give sufficient power to drive the furnace blower, then the power becomes the required result and the 150# steam the by-product. We all know that the demands on a blast furnace blower are irregular, even during a single campaign, both from the quantity of iron desired and the reactions of the furnace increasing or decreasing the normal amount of power required for blowing. Let us assume that 210,000 pounds of 150# steam are required per hour; now that amount of steam expanding from 450# pressure will produce turbine horsepower sufficient for 70,000 C. F. M. against 18# blast pressure. If the furnace requires more power than this, then more 150# steam will be produced than is required. If the power requirements decrease, less 150# steam will be produced than is required. It is evident then that in the normal daily operation of the plant we must be able to produce economically both the instantaneous requirements of 150# steam and the power to blow the furnace. It is further evident that when we consider the probable decrease in 150# steam demand, either with or without an increased demand for blowing power, it will be impossible to obtain an economical combination of costs of 150# steam and furnace blowing with a simple non-condensing turbine.

As a homely simile, consider the purchase of a truck for a new farm when at present its use will be hauling away field stones, but eventually it will be required to handle all farm products.

First—the farmer can buy a low-hung truck so as to require the least effort in getting the stones out of the field and away. This would correspond to a straight non-condensing turbine for this study.

Second—The farmer can buy a regular truck not especially suited for hauling stones, at the present, or hay, etc., in the future, but usable for these services. This would correspond to a straight bleeder turbine for this study.

Third—The farmer can buy a regular truck and load his stones onto a low-hung trailer and in the future his hay onto a hay rack. This corresponds to a compound unit consisting of a straight non-condensing turbine plus a turbine expanding from 150# steam to a vacuum in this study.

The more study we give to the widely varying requirements of 150# steam and power from this turbo blower in all the years of its life, the clearer it shows that neither a simple non-condensing nor a conventional bleeder turbine will give the proper solution. Mr. Clarke has shown, I believe, the logical answer to this problem.

C. W. E. Clarke: Well, of course, that's entirely true; and, if you design a bleeder turbine and try to run that turbine on a straight condensing cycle, your wheel efficiencies are going to fall off. In other words, your blading is too large in certain points in the turbine.

A. I. & S. E. E. PHILADELPHIA DISTRICT SECTION

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Schaff Building, Philadelphia, Pa.

A CAMPAIGN FOR NEW USES FOR STEEL

(Continued from page III)

7. When visiting department stores, see what you can find that should be made OF STEEL.
8. If you see a new building or a new home under construction, try to find some new use FOR STEEL.
9. When out for a ride along the highway, try to find a new use FOR STEEL.
10. When attending the theatre, see what could be made OF STEEL.
11. When dining at the hotel, see what could be made OF STEEL.
12. When talking to an architect, an engineer, a contractor or a builder suggest the use OF STEEL.
13. Check up on all road building and excavating and see if they could make more use OF STEEL.
14. When riding on the trains check up the car construction and see what should be made OF STEEL.
15. Do you know of any mechanical device or piece of mechanical equipment which should be made OF STEEL?
16. Is there any part of electrical equipment that you feel should be made OF STEEL?
17. Is there any package or container of any size now being made that you feel should be made OF STEEL?
18. What kitchen utensils could you suggest to be made OF STEEL?
19. What new type of ceiling or wall lining could you suggest to be made OF STEEL?
20. What new application could you suggest for the use OF STEEL on—

    Motor Trucks

    Wagons

    Automobiles

    Street Cars

    Passenger Cars

    Freight Cars.

21. What practical standard toys could you suggest to be made OF STEEL?
22. What STEEL application could you suggest in the following industries:

Food Industry:

Meats
Wheat—Flour
Sugar—Meltings
Ice Cream
Butter
Cheese
Condensed Milk
Glucose and Starch
Rice
Cotton
Wool

Lumber Industry:

Flooring
Lumber—Saw Mills

Leather Industry:

Tanneries
Boot and Shoe Factories

Paper and Printing Industry:

Wood Pulp
Paper Mills
Printing Presses

Chemical Industry:

Coke
Petroleum
Cotton Seed Oil
Turpentine
Rosin

Stone Quarries:

Brick Yards
Bottling Works
Cement Plants
Potteries and Glass Factories

Tobacco Industry:

Cigar Factories
Cigarette Factories

Ship Building:

Boats
Ship Yards
Docks
Piers
Gang Planks

Rubber Industry:

Tire Manufacturers

Textile Industry,

Coal Industry,

Agricultural Industry:

Motion Picture Industry:

Mining and Mineral Industry,

Gas and Gasoline Plants,

Machinery and Tools,

Suggestions FOR STEEL containers to carry fruits, vegetables.

Suggestions for the application OF STEEL to baths, sinks, lavatories.

Suggestions for the application OF STEEL to shelving in department stores.

Suggestions FOR STEEL containers to carry fish, eggs, poultry.

ITEMS OF INTEREST

PERSONNEL CHANGES

▲

Henry E. Davis has been appointed to the superintendency of both the Mechanical and Electrical departments of the Republic Steel Corporation at Chicago.

HENRY E. DAVIS

Mr. Davis is a very active member of the A. I. & S. E. E. having served as Chairman of the Chicago Section and as a member of the board of directors and at the present time serving on important national committees. The Association wishes at this time to congratulate Mr. Davis on his advancement and continued success in his new capacity.

▲

S. H. Mortensen has been appointed engineer in charge of all alternating current design for the Allis-Chalmers Mfg. Co., Milwaukee, to succeed the late R. B. Williamson. Mr. Mortensen was first assistant to Mr. Williamson for many years.

▲

The Thomson-Gibb Electric Welding Company, with plants at Lynn, Mass., and Bay City, Mich., announces a new department for the manufacture of a complete line of wire mill and stranding machinery.

A. R. Petterson, formerly with the American Steel & Wire Company, and also formerly chief engineer for the New England Wire Machinery Company, will have charge of the sales and engineering work.

▲

Glenn E. Weist, formerly sales engineer with the Milwaukee Electric Hoist Division of the Harnischfeger Company, Milwaukee, has joined The Kron Company, Bridgeport, Conn., manufacturers of Automatic dial scales for all industrial uses.

▲

Dr. Willis Rodney Whitney, organizer and for 32 years director of the famous research laboratory of the General Electric Company, retired from that position owing to poor health on November 1. He was succeeded, by appointment of Gerard Swope, president of the company, by Dr. William David Coolidge, senior associate director of the laboratory. Dr. Whitney continues as vice president in general charge of research.

Dr. Coolidge, the new director, was appointed assistant director of the laboratory in 1908, and associate director in 1928, a title also held by Dr. Langmuer.

▲

Appointment of Fred C. Archer as manager of the Philadelphia district is announced by The Lincoln Electric Company, Cleveland, Ohio.

The Philadelphia office of The Lincoln Electric Company is located at 401 North Broad street.

▲

Mr. R. O. Watson, Manager of the Large Motor Section of the Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa., has also been put in charge of the Medium D-C Motor activities and his new duties will encompass both the managership of the Medium D-C and the Large Motor Section.

R. O. WATSON

Mr. Watson has been an associate member of the A. I. & S. E. E. for eight years and has taken a very active part on the tabulation committee in connection with the electrification of Main Roll Drives. The A. I. & S. E. E. wishes at this time to congratulate Mr. Watson on his advancement and wishes him continued success in his new capacity.

▲

The Roller-Smith Company, 233 Broadway, New York, N. Y., announce the following appointments:

Mark G. Mueller, 1700 Sixteenth street, Denver, Colo., as the District Sales Agent for the States of Colorado and New Mexico and for the western part of Kansas.

Burkholder and Kelley, 105 Cortleigh Boulevard, Toronto, Ontario, Canada, as the District Sales Agent for the Dominion of Canada.

▲

F. J. Rudd has been appointed managing engineer of the motor department of the General Electric Company, it has been announced by N. J. Darling, manager of the River Works at Lynn, Mass. He succeeds L. E. Underwood, who has been made manager of the Pittsfield, Mass., works of the company.

▲

Farrel-Birmingham Company, Inc., 344 Vulcan Street, Buffalo, N. Y., has announced the appointment of E. J. von der Heide as sales representative to handle Farrel-Sykes Gears, Gear Units and Gear Generators in the middle west territory.

Mr. von der Heide's headquarters are at 824 Miami Savings Building, Dayton, Ohio.

WITH THE MANUFACTURERS

▲

A new type electrode holder has been developed by the General Electric Company for atomic-hydrogen arc-welding with flexible tungsten electrodes. These flexible electrodes are carried in curved tubes, forming a part of the holder, and are brought into position through the means of a screw feed ejector. Not only should the new electrode holder make it easy for the operator to work in confined places, but the flexible electrodes should materially lower the operating cost by reducing breakage.

The flexible tungsten electrode is made up of several small diameter tungsten wires which have been stranded together, and, as a result, the electrode is so flexible that the ends of a 12-inch length can be brought together without giving the electrode a definite set. The consumption of this electrode is the same as that of the rod type electrode.

When using the rod type holder, the operator has a tendency to discard the electrode after it has been consumed to a length of three or four inches because of the difficulty of adjusting the shorter lengths. In the new holder, the electrode is easily adjusted, by means of the screw feed ejector, and can be consumed to a length of approximately one and one-half inches, at which point the electrode will drop out of the nozzle tip. Before this occurs, a new electrode has been mechanically inserted into the ejector and a few turns of the screw feed places the electrode in welding position.

On holders of the rod type, the hydrogen tubes are moulded into the handle and, therefore, whenever these tubes have to be repaired or replaced, it is generally necessary to return the holder to the factory. The tubes of the new holder are easily detached from the handle and the purchaser can make any necessary replacements at his own plant. Likewise, all other wearing parts have been arranged for quick and easy replacement.

Another feature of the new electrode holder is its adjustment for controlling the position of the fan-shaped welding flame. The flame may be controlled to be either parallel to or at right angles with the axis of the handle by a slight turn of a thumb screw.

The Brown Instrument Company, Philadelphia, Pa., have just published a broadside featuring the announcement of the new Brown Mechanical Flow Meter.

A copy of this broadside will be sent to interested parties upon request.

▲

"Lubrication of New Departure Ball Bearings" is the title of the latest bulletin being distributed by the New Departure Manufacturing Company of Bristol, Conn. The bulletin is well illustrated and contains valuable information on lubrication. Interested parties may secure copies by writing the New Departure Company.

▲

Bulletin 1908 on "Single Stage Turbo-Blowers" is being distributed by the Allis-Chalmers Manufacturing Company of Milwaukee, Wis. Copy of the interesting 4-page bulletin may be secured by writing the above company.

▲

The Surface Combustion Corporation, Toledo, Ohio, have prepared an attractive 12-page booklet on Industrial Furnace and Burner Equipment. The illustrations in the booklet show a few of the different types of Surface Combustion Burners, Standard Furnaces and Special Furnaces. Copies of this booklet may be obtained by writing the above company.

▲

The Engineering departments of Bryant Machinery & Engineering Co., of Chicago, Ill., and The Imperial Electric Company, Akron, Ohio, have developed the new Imperial Arc Welder. A 6-page Bulletin No. S-584 is now ready for distribution on this new welder and copy will be sent to interested parties on request. T. M. Rees is representing the Bryant Machinery & Engineering Co. in the Pittsburgh district.

▲

The Reliance Constant Tension Drive, for application to any process requiring a constant tension in material being wound onto or unwound from a reel is described in a new Bulletin 602. The bulletin is illustrated by photographs and drawings and may be secured by writing the Reliance Electric & Engineering Co., at Cleveland, Ohio.

▲

A new line of unit pedestals for pillow blocks is announced by the Norma-Hoffmann Bearings Corporation, Stamford, Conn. This is designated as the "LUP" Series and is adapted to all average industrial requirements, in sizes to fit standard shafting in nominal inch as well as sixteenth diameters, from 15/16-inch to 3½-inch. The ball bearings are the standard Norma-Hoffmann "Precision" double-row, self-aligning type with adapter sleeve. The pedestals have capacity for a large volume of lubricant, with fittings for replenishing as needed. Protecting felt seals prevent escape of lubricant along the shaft. These pedestals may be had with the bearings either floating or fixed in the housing. In the latter case,

suitable distance pieces are furnished for clamping the outer ring.

▲

On October 3 the Keystone Lubricating Company's plant at Twenty-first, Clearfield and Lippincott streets, in Philadelphia, was burned to the ground and two days later the contract was signed to rebuild on the same site and on the same foundations, a building with every improvement that modern ideas can suggest and that 48 years of experience have developed through untiring efforts since the establishment of the business in 1884.

H. A. Buzby, the president of Keystone Lubricating Company, when interviewed said that this new building and equipment would bring to their plant all the newest machinery and methods which would result in greater efficiency and even higher quality of products than ever before.

Operations will start at once for rebuilding the plant. The work is planned in such a way that the plant will be operating while the administrative portions of the structure are still unfinished. During construction the temporary offices of the company are across the street in the building of Steel Heddle Manufacturing Company, Twenty-first and Allegheny avenue.

▲

Woodward Iron Company has placed a contract with Freyn Engineering Company for four Freyn-Design Pressure Burners for installation on hot blast stoves at its No. 1 blast furnace at Woodward, Ala. These pressure burners are of an improved design, utilizing an improved type of burner nozzle, the new Linatex gas shut-off valve and an improved type of combustion controller.

▲

Harnischfeger Corporation, 4400 West National avenue, Milwaukee, Wis., has just issued a new instructive catalog called "Weld It Well."

This fully illustrated book on the latest developments in welding practice and welder design covers many interesting phases of arc welding. Several pages are devoted to direct illustrated comparison of old time practice and modern welding methods.

New models of P&H Hansen Arc Welders are described in another section of this issue. Copy of above bulletin No. HW-2 may be secured by writing above company.

▲

Artistically-proportioned square cases designed to utilize a minimum of switchboard space feature the new H line of instruments announced by the Westinghouse Electric and Manufacturing Company, Newark, N. J.

This new line includes ammeters, milliameters, voltmeters, milli-voltmeters, single and polyphase power factor meters, frequency meters, and synchroscopes. Both A.C. and D.C. instruments are intended for service on large switchboards of steel, ebony asbestos, or slate. Radio frequency and rectifier designs are available for low energy A.C. applications.

Westinghouse offers a complete description of the type H instruments in Leaflet 20545, an illustrated, eight-page publication.

A new small size crane limit safety stop, with standard mill type blowouts and contact tips, has been developed by Cutler-Hammer, Inc., Milwaukee, Wis. These stops are used to prevent over-travel of the hoist on electric cranes.

Rated for 40 HP. and under, it is claimed the new stop is unusually small and compact for this rating, taking only 9 inches head room. The Stop is supplied complete with leads equipped with soldering lugs. The cover is removable for inspections and repairs.

▲

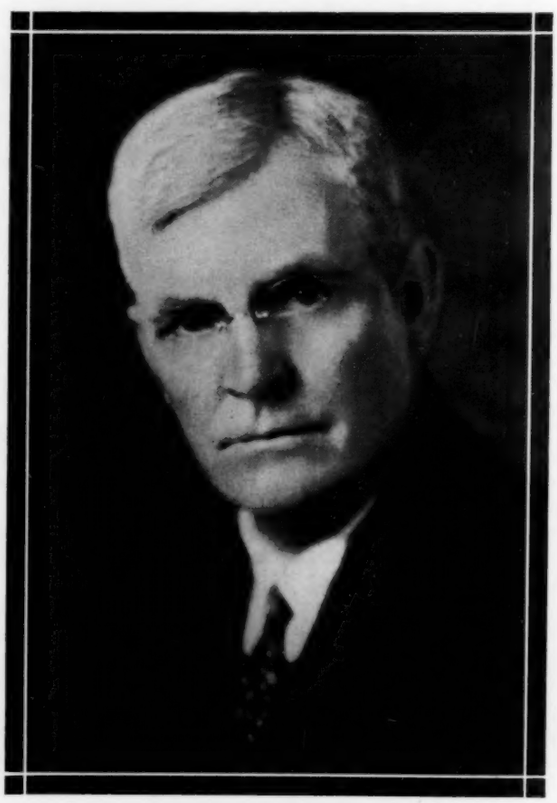
Propeller pumps, which are axial flow pumps for handling relatively large volumes of liquid against comparatively low heads at high rotative speeds, are described in Catalog B-6, distributed by the De Laval Steam Turbine Co., Trenton, N. J. Copy may be obtained on request.

IN MEMORIAM

▲

Charles S. Proudfoot, General Manager, Vanadium Corporation of America, Niagara Falls, New York, died at the Memorial Hospital, Niagara Falls, on October 29, following an operation.

Mr. Proudfoot began his steel mill career in 1892 at the Homestead Works of the Carnegie Steel Company in the Electrical Department being associated with the late A. C. Dinkey up until 1904 and to 1918 with the late C. A. Menk. In 1918 Mr. Proud-



C. S. PROUDFOOT

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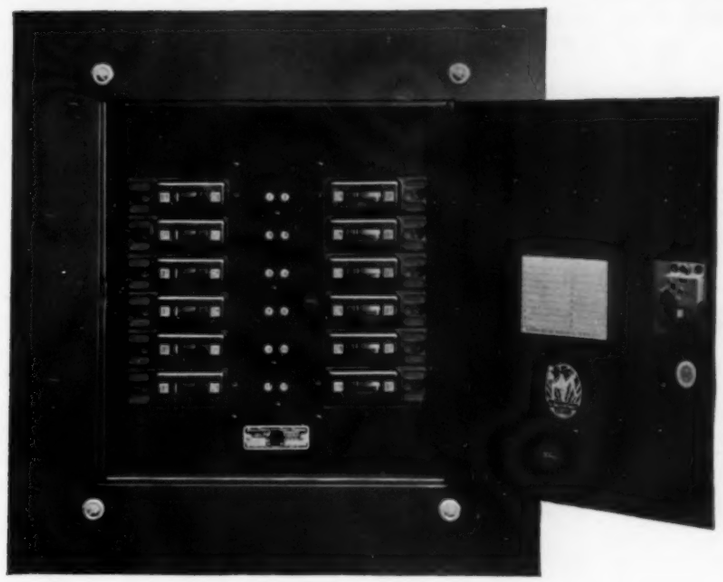

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Lighting panels are furnished with 4 to 40 circuits; power panels in capacities, up to 600 amperes. Circuit breakers can be secured in individual cabinets, 2 and 3 pole, up to 600 amperes capacity.

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Recently completed negotiations fully protect Buyers and Users of BULL DOG Circuit Breakers against patent infringements.

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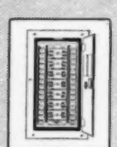
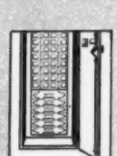


SUPERBA Lighting Panel

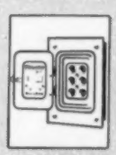


SAFtoFUSE Feeder Panel

SAFETY SWITCH

Bus-DUCT

Trol-e-DUCT



FUSENTER

SAFtoSWITCH-BOARD

foot was appointed electrical engineer of the Bethlehem Steel Company, Johnstown, Pa., under the supervision of A. A. Cory. In 1925 Mr. Proudfoot was appointed General Manager of the Vanadium Corporation of America at Niagara Falls in which capacity he served up until his death on October 29.

Mr. Proudfoot was an active member of the A. I. & S. E. E. for 24 years. He served on many national committees and was President of the Society in the year 1928-1929. At the time of his death he was Chairman of the National Papers Committee.

Mr. Proudfoot was one of the most progressive leaders in the progress of Electrification in the Steel Industry. His achievements were many among them being: The Blast Furnace Bell Operated Rig, which later helped in a large degree to make possible the Automatic Blast Furnace and the supervision of the design and installation of a modern power house, and the installation of all the electrical apparatus in connection with five modern mills.

The A. I. & S. E. E. wishes to take this opportunity to express to the family and associates of Charles S. Proudfoot their deepest sympathy for the loss of an individual who was a progressive in thought and action and an outstanding leader in the steel industry.

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Tinius Olsen, aged 86, known internationally as a designer and manufacturer of testing machines, died at Philadelphia, October 20.

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ASSOCIATION NOTES

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COMING MEETINGS AND PAPERS

PHILADELPHIA SECTION

Saturday, December 3, 1932

"Keeping Step With Industrial Lighting Progress," P. R. Holmes, Illuminating Engineer, Incandescent Lamp Department, General Electric Company, Philadelphia, Pa.

Inspection of Lighting Exhibit of the Electric Association of Philadelphia, in the Architect's Building.

Saturday, January 7, 1933

"Heat Distribution in Gas, Oil and Electric Furnaces," J. W. Allison, Westinghouse Electric and Manufacturing Company, Philadelphia, Pa.

Saturday, February 4, 1933

"The Use of General Purpose Alternating Current Motors for Special Applications," A. M. MacCutcheon, Vice President in Charge of Engineering, Reliance Electric & Engineering Company, Cleveland, Ohio.

Saturday, March 4, 1933

"Locomotives for Shifting Service in Industrial Plants," D. M. Petty, Superintendent of Service Division, Bethlehem Steel Company, Bethlehem, Pa.

Saturday, April 1, 1933

"General Ideas and Discussion." Every Active Member is invited to prepare a short paper on a subject pertaining to the application of Electricity to the Iron and Steel Industry.

"Reduction of Power Costs by the Use of Modern Equipment," George C. Pfeffer, Chief Electrician, Florence Pipe Foundry & Machine Company, Florence, N. J.

"Employees Suggestion Systems," Walter H. Burr, Superintendent Electrical Department, Lukens Steel Company, Coatesville, Pa.

"Non-Metallic Bearings," L. F. Coffin, General Master Mechanic, Bethlehem Steel Company, Sparrows Point, Md.

"Factors Encountered in Changing From Manual to Automatic Control on Nine-Inch Mill Main Roll Drive," G. O. Van Artsdalen, Electrical Superintendent, Henry Disston & Sons, Inc., Philadelphia, Pa.

All meetings, except the December Meeting, will be held in the Engineers' Club, 1317 Spruce street, and will start promptly at 7:00 P. M. They will be preceded by an informal dinner at 6:00 P. M.

The privileges of the Engineers' Club are at the disposal of the Members on the date of the meeting. Make the Club your headquarters.

BIRMINGHAM SECTION

November, 1932

"The Akron" by V. R. Jacobs, Sales Manager, Goodyear Zeppelin Co., Akron, Ohio.

CLEVELAND SECTION

December, 1932

"Selection of Synchronous Motors for Main Roll Drives" by Westinghouse Electric & Mfg. Co., General Electric Company and Electric Machinery Mfg. Company.

PITTSBURGH SECTION

December 10, 1932

"The Application of Synchronous Ties to Modern Control Problems," by R. H. Wright, General Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

January, 1933

"Practical Methods for Inductive Heating of Solids" by Dr. E. F. Northrup, Ajax Electrothermic Corp., Trenton, N. J.

"Precision Measurements of Mechanical Dimensions by use of Electricity" by F. B. Perry, Assistant Manager, Gauge Division, Pratt & Whitney Co., Hartford, Conn.

"The Application of Thyratron Control to Resistance Welding and Some of the Results Acomplished" by H. A. Winne, Industrial Engineering Dept., General Electric Company, Schenectady, N. Y.

CHICAGO SECTION

November 15, 1932

"Rossman System of Adjustable Speed Drive" by A. M. Rossman, Sargent & Lundy, Inc., Chicago, Ill.

December 7, 1932

Christmas Reception.

January 11, 1933

"Shop Practices" by V. E. Schlossberg, Assistant Superintendent, Electric & Power Dept., Inland Steel Co., Indiana Harbor, Ind.